SCIENCE

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*EXPLOSIONS CAUSED BY COMMONLY OCCURRING SUBSTANCES.**

ON the sixth of November last the country was startled by learning that an explosion had occurred in the Capitol at Washington which had caused extensive damage to that magnificent and historic building, and which, with the ensuing fire, had destroyed some and jeopardized more of the valuable archives with which the building was stored. Occurrences of this kind have long had a particular interest for me, and I have found them to recur with great frequency and to cause extensive damage and destruction not only to property but to person. Notwithstanding, therefore, that much that I have to say is well known, it appears to be not inopportune to address you on the subject of 'Explosions Caused by Commonly Occurring Substances,' ommitting entirely from consideration the substances commonly known and used as explosives, and it is possible that this repetition may serve to some extent in preventing these accidents by leading to greater precautions being taken.

From the observations on the phenomena accompanying the combustion of solids it is well understood that the speed of the combustion is greatly accelerated by comminuting the combustible and mixing it in-

* Address of the President before The American Chemical Society, New York Meeting, December, 1898.

timately with the supporter of combustion, and it is also well recognized that many explosions are due solely to very rapid combustion, yet it is only within comparatively recent times, and since manufacturing operations have come to be carried on upon a very considerable scale, that we have had it strongly demonstrated that ordinarily combustible solids might, when finely divided and mixed with air, give rise, on ignition, to most violent and disastrous explosions, and it seems especially notable that the first well demonstrated cases of this kind should have arisen from the apparently harmless operations attending the grinding grain, and the more particularly as flour is not looked upon as a very readily combustible substance when compared with other commonly used solids.

Among the many instances of this kind which we have now on record we will cite that which occurred on the 9th of July, 1872,* when the inhabitants of Glasgow were startled by the report of an explosion which was heard to a considerable distance and which was found to have occurred in some very extensive flour mills, the front and back walls of which were blown out, while the interior was reduced to ruins, and speedily enveloped in flame which destroyed the remaining buildings. Several persons were killed, and a number of others were severely burned, or injured by the fall of masonry.

On May 2, 1878, a similar disaster occurred in the enormous flour mills in Minneapolis, but in this case it was observed that the explosion which originated in the Washburn mill was communicated by flame successively to the Diamond mill and to the Humboldt mill. As a consequence of these explosions, the walls of these mills, which were solid masonry, six feet thick at the base, were razed to the ground; sheets of corrugated iron roofing, two by six feet in area, were projected to a distance of more than two miles; a wooden building fifty feet from the center of explosion was burst open; stout plate glass windows one-fourth of a mile away were torn out bodily, sash and all, and projected into the street; an immense volume of smoke and flame was projected to an estimated height of six hundred to eight hundred feet, and finally persons by the edge of the adjacent river observed a displacement of water, producing a wave estimated to be eighteen inches high, before they heard the report of the explosion. The concurrent testimony of persons employed in the mills, and of the experts who were called, proved the absence in each case of any of the so-called explosive substances on the premises and that the boilers had not burst, and from the facts brought out the origin was conclusively traced to the striking of fire by a pair of mill-stones, through the stopping of the 'feed,' and the consequent friction of their bare surfaces against each other, with the result that the mixture of air and fine flour-dust surrounding the millstones became ignited.

This ignition alone would not suffice to develop any violent explosive effects; for similar ignitions which have been not infrequently observed in small mills, where they have been caused by the stones 'striking fire' or by the incautious use of a burning lamp near the millstones, or the meal-spout attached to them, have not been attended by any serious results. But in an extensive mill, where many pairs of stones may be at work at one time, each pair has a conduit attached, which leads to a common receptacle called an exhaust box; into this the mixture of air and very fine flour-dust which surrounds the millstones is drawn by means of an exhaust fan, which is sometimes aided by a system of air-blowers. The fine flour is allowed to deposit partially in this chamber or exhaust box, and the air then passes into a second cham-

* Abel, Roy. Inst., March 12, 1875.

ber, called a stive room, where a further quantity of dust is deposited. It follows that when the mill is at work, these chambers and the channels are all filled with an inflammable mixture of the finest flour-dust and air, and that the ignition of any portion of the inflammable mixture will result in the exceedingly rapid spread of the flame throughout the whole, and will thus develop an explosion. The violence of such explosions depends much upon the details of construction of the exhaust boxes and stive rooms, and upon the dimensions of the channels of communication; it must obviously be regulated by the volume of the inflammable mixture through which the fire rapidly spreads, and upon the degree of confinement. In the case of the catastrophe at Glasgow the production of a blaze at a pair of millstones was observed to be followed by a crackling noise as the flame spread rapidly through the conduits leading to the exhaust box upon an upper floor, and a loud report from that direction was almost immediately heard. Professors Rankine and Macadam, who carefully investigated the cause of this accident, report* that other flour-mill explosions which they had inquired into had been observed to have been attended by a similar succession of phenomena to those noticed upon this occasion. The bursting open of the exhaust box by a similar though less violent explosion, attended by injury of workmen, the blowing out of windows and loosening of tiles, appears to have taken place on a previous occasion at these particular mills. In the last and most disastrous accident, however, the more violent explosion appears to have been followed by others, the flame having spread with great rapidity to distant parts of the mills through the many channels of communication in which the air was charged with inflammable dust, resulting from the cleansing and sifting operations carried on in different parts of the building, and rapidly diffused through the air by the shock and blast of the first explosion.

In the experimental investigation of the Minneapolis explosion by Professor S. F. Peckham* it was shown that compacted masses of flour which had become heated and charred ignited readily and smouldered, but were inflamed only with considerable difficulty, though the atmosphere of the conduit from the stones, through which a strong current of air is being continually drawn and which is filled with a dense cloud of very fine particles of flour heated to a maximum temperature of 140° F, could be inflamed with comparative ease. White-hot wires and glowing charcoal were incapable of producing this inflammation, and only burned the particles in actual contact with them, and the only means by which the mixture, in the best proportions, could be made to burn explosively was by contact with flame.

The danger in the process was found to arise from the friction of the stones heating the last portion of the grist that remained between them to a temperature sufficient to char it or to convert it into a substance resembling tinder, which would readily ignite from a spark produced from the stones striking together. Although this burning mass could not inflame the dust-laden atmosphere, it did ignite wood, which a strong draught of air readily forced into a blaze. Under the conditions described with a draught of air passing through the dry stones strong enough to convey the pellets of smouldering tinder into the wooden conductor an explosion was a necessary consequence.

Knowing the chemical composition of flour, we may calculate approximately the mechanical work which a given mass of flour can perform, and find that the con-

* Abel, Roy. Inst., March 12, 1875.

* *Am. J. Sci.* 16 (3), 301–306; 1878.

tents of an ordinary sack, when mixed with 4,000 cubic feet of air, will degenerate force enough to throw 2,500 tons mass to a height of 100 feet. If we now consider the many tons of flour there must have been in a mill such as the Washburn 'A,' where as much as 1,000 pounds of dust per day was collected from a single pipe, we can readily comprehend how such great destruction could be wrought.

It is to be regretted that the experts who duly considered all the circumstances concluded that, while, by suitable precautions, the frequency of these flour-mill explosions may be diminished and the extent of the damage inflicted may be very much restricted, the nature of the operations is such that these explosions cannot be altogether prevented.

Since mixtures of wheat-dust with air have proved to be so explosive, we should naturally expect that analogous solids would form similar explosive mixtures with air, and, as a fact, we have recorded explosions of oatmeal in the Oliver mill in Chicago, of starch in a New York candy factory,* of rice in rice mills, of malt dust in breweries, of spice dust in spice mills, together with numerous instances of sawdust explosions, the more prominent being those which occurred in the Pullman car shops and at Geldowsky's furniture factory in Cambridge, Mass., still we should scarcely look for an explosion from such a cause in a soap factory. Yet a violent explosion occurred in 1890, in a Providence soap-works, in which the finely powdered saponaceous substance known by the trade name of 'Soapine' was being prepared, and the Coroner held in his finding that the explosion through which such injury was inflicted was caused by the ignition of soapine dust. Experiments made in this connection showed that this substance will explode under certain conditions with more violence than flour and apparently with the production of more heat.

The most unusual case of dust explosions, however, with which we have met was that of finely powdered metallic zinc which occurred at the Bethlehem Zinc Works in 1854. At that time Col. Wetherill devised a plan for utilizing the 'blue powder' which is the finely divided metallic zinc that is deposited in the prolongation of the condenser by swedging the powder into blocks and piling these blocks one above another in a furnace where they were melted down and run into spelter. The workmen in charge sought to facilitate the process by feeding the uncompressed powder directly into the furnace, but on trying to do so an explosion followed the loading of the first shovelful, and with such violence that the workman was blown from the top of the furnace and the blade of the shovel was driven into the roof of the building.

In pharmacy and the arts substances have been made either knowingly or accidentally from mixtures of combustible substances and supporters of combustion which have given rise to accidents, such as those from the parlor match and the chlorate troches,* or from sodium peroxide and sodium bisulphite mixtures, as in the Whitecross Street explosion,† and the latter class of mixtures are to be particularly dreaded as the chemical action and subsequent explosion may be incited not only by contact with fire, but also by contact with water. Cavazzi ‡ points out that mixtures of sodium nitrate and hypophosphite detonate on heating, while Violette § proposed to use a mixture of sodium nitrate and acetate as a substitute for gunpowder, and these are but a few among the many explosive mixtures which may be compounded.

* L. W. Peck, Explosions from Combustible Dusts, *Pop. Sci. Month.*, 14, 159–166; 1878.

* *U. S. Nav. Inst.* **11**, *774*; 1885.
† J. Soc. Chem. Ind. **13**, *198–200*; 1894.
‡ Gaz. Chim. Ital., 1886.
§ Berthelot sur la force de la poudre (3) **2**, *315*.

Still another source of danger arises from the production and use in laboratories, and, frequently in common life, of chemical substances which are explosive *per se*, though not generally recognized as such, and we have records of accidents, among others, from bleaching powder,* from erythryl nitrate, which has lately come into use in the treatment of Angina Pectoris,† from ammonia nitrate,‡ and there are many others, such as the organic nitrates,§ nitroso compounds,‖ diazo bodies,¶ diamides,** hydrozoic acid and its derivatives,†† hydroxylamines, ‡‡ chlorates,§§ carbonyl compounds,‖‖ permanganates, ¶¶ peroxides,*** chlorides††† and iodides,‡‡‡ occurring in the laboratories and used to a varying extent in the arts that are so unstable as to give rise to serious accidents if incautiously handled. We may notice that so well known a compound as the cupric ammonium nitrate, a body which is often formed in the course of analysis, was deemed by Nobel to possess such value as an explosive that he took out patents for its use in blasting.

The liquid state conduces more particularly to accidents taking place since bodies in this state are liable to escape from their receptacles and to be found in unexpected places. If combustible, when mingled with the atmosphere or when saturating oxidizing agents they burn with extreme rapidity and produce very violent effects. When such liquids give off vapors at the ordinary temperatures, or those prevailing during use, the danger is very materially increased, as such vapors are more vagrant and, through diffusion, readily mingle with the atmosphere. These properties are especially characteristic of many of the products obtained from coal tar and from petroleum, bodies whose cheapness, abundance and special adaptability have led to their extended use for domestic heating and lighting and for many purposes in the arts, but which have, because of this widespread use and in consequence of their possessing the properties named, been the cause of an enormous number of casualties. Dr. C. F. Chandler* showed that much of the danger attending the use of these oils in lamps could be avoided by the elimination of the paraffines of low boiling points, and though not the pioneer, yet largely through his active efforts and the agitation which followed them, this principle has properly become widely embodied in legislation. This view as to the source of danger was confirmed by the experiments of Newbury and Cutter,† who found that all the paraffines below nonane formed explosive mixtures with air at the ordinary temperatures, notwithstanding that the boiling point of octane is 124°C., and that the limit of a safe oil as fixed by the 'flashing test' defined by the New York State statutes is reached only in decane. Yet this last-named compound formed a violently explosive mixture at the legal flashing temperature if but a small quantity of the liquid was placed in the copper testing vessel, thus indicating that entire safety is not assured in its use and that accidents might occur when it is used in lamps so constructed that the oil chamber becomes highly heated. Dewar‡

* Rept. H. M. Insp. Exp. pg. 47; 1897.
† Rept. H. M. Insp. Exp. pg. 50; 1898.
‡ J. Chem. Soc. 683; 1882.
§ Compt rend **109**, *92–95;* 1889.
‖ Comp. rend **108**, *857–859;* 1889.
¶ Annalen **121**, *257;* 1860.
** J. Prk. Chem. **30**, *27;* 107.
†† Bericht. **23**, *3023;* 1890.
‡‡ Rec. d. trav. Chim. Pays Bas **10**, *101;* 1891, and J. Chem. Soc. **54**, *425;* 1888.
§§ Compte rend. **105**, *813;* 1887.
‖‖ Bericht. **18**, *1833;* 1885.
¶¶ J. Chem. Soc **54**, *230;* 1888.
*** Compte rend. **106**, *100;* 1888.
††† Bull. Soc. Chim. **50**, *635–638.*
‡‡‡ J. Chem. Soc. **56**, *766;* 1889.

* Petroleum as an Illuminator; Rept. N. Y. City Board of Health for 1870.
† Am. Chem. J. **10**, 356-362; 1888.
‡ Rept. H. M. Insp. Exp. **21**, *55;* 1897.

holds that the relative volatility of petroleum oil is a subject which is not sufficiently known and appreciated. By comparing the loss of weight during 24 hours of oils exposed in shallow vessels under similar conditions, he found at 66°F. an American water white oil of 106° flash point lost 20.4 per cent., an oil of 75° flash point lost 27.4 per cent., and a Russian oil of 84° flash point lost 28 per cent.

In observations that I have made it was very apparent that the form and material of the containing vessel are most important factors in these volatilization experiments. I have found, for instance, that a given volume of gasoline placed in an uncorked vial and exposed to the ordinary atmospheric conditions of a laboratory required 10 weeks for complete volatilization when the same volume of the same lot of gasoline placed in an evaporating dish standing beside the bottle volatilized completely in 8 hours. The rate of evaporation of various hydrocarbons under the same conditions has been studied by Boverton Redwood.*

A menace in the use, storage and transportation of these liquids rests in the rapidity with which their vapors diffuse through the air and form an explosive train which reaching out to a source of ignition flashes back with extreme rapidity through the entire train and to its point of origin. Sir Frederick Abel cited an instance of this† which happened at the Royal College of Chemistry in 1847 when a glass vessel in which benzene was being converted into nitro-benzine broke and allowed the warm liquid to escape and flow over a large surface. Though the apartment was 38 feet long, 30 feet wide and 10 feet high, and the only ignited gas jet was at the end of the room most remote from the glass vessel, yet, in a very brief space of time after the vessel broke, a sheet of flame flashed from the gas jet and traveled along the upper part of the room to the point where the fluid lay scattered.

Also he cites the explosion of benzoline at the mineral oil store in Exeter in 1882. The store rooms were arched caves in the side of a bank facing a canal and separated from it by a roadway about 50 feet wide. There was a standing rule forbidding any light being taken to any of these store rooms when they contained petroleum spirit, but on the day in question it was desired to remove some of the benzoline in the early morning and the foreman visited the store rooms before daylight to make ready for the work. Forgetful of the rule, he carried a lighted lantern, which he placed on the ground some 27 feet away from the cave, and was proceeding to open the door when he observed a strong odor of benzoline and almost immediately noticed a flash of flame proceed from the lantern to the store and had barely time to turn to escape when an explosion took place which blew the doors and lantern across the canal and inflamed the spirits in the store rooms.

Of course, the distance that these vapors will travel will be determined by the circumstances of each individual case, but in the case of the fire at the L. & N. W. R. R. Co.'s gas factory in February, 1897, through which the hydrocarbons in a cylinder that was being rolled across the yard about the works became ignited, the nearest source of ignition was found in the boiler fires, which were 60 feet away.*

Conditions such as these are more likely still to obtain when these inflammable and volatile substances are stored in enclosed spaces, such as the hold of a vessel during transportation, and they have been the cause, under these conditions, of many frightful accidents. As an example of these we have the case of the explosion on Novem-

* 'Detection of Inflammable Gas and Vapor in the Air,' Frank Clowes, p. 191, 1896; London.

† Roy. Inst. of Great Britain, March 13, 1885.

* Rept. H. M. Insp. Exp. **22**, *57;* 1898.

ber 21, 1888, on the petroleum-laden ketch 'United' at Bristol, England, through which the docks were blown up, three men killed and several injured, the glass in the windows shattered for a radius of upwards of 300 feet, and extensive damage done by fire.

The accident was made the subject of a special report by Col. V. D. Majendie* which contains the results of his investigation and the experiments by Dr. Dupré and Mr. Boverton Redwood, from which it appears that the material on the 'United' was 'deodorized naptha' in forty-two gallon barrels; that the average annual leakage on petroleum oil in barrels amounted, in 1874, to 8 per cent. and on petroleum spirit to double this quantity, and that, though there has since been a great improvement in the treatment of the barrels, it is still very large; that one volume of the liquid gives 141 volumes of vapor at ordinary temperature having a specific gravity of 3.5 to 3.8; that one volume of the liquid will render 16,000 volumes of air inflammable, 6,000 most violent explosive, 5,000 strongly explosive, and 3,000 scarcely explosive but combustible. The naptha vapor alone or when mixed with air in the best proportions was not ignited by a shower of sparks from flint and steel; by a stream of sparks from fireworks of various kinds burning without flame; by incandescent match ends, or by incandescent platinum heated by electricity to a red heat. Even red-hot coals held over and sometimes falling upon a small quantity of the spirit spilled on a wooden floor failed usually to ignite it, and the cause in those cases in which ignition did take place in these red-hot coal experiments was uncertain, as there was a fire burning in a near by room. Ignition was, however, certainly effected by the application of a flame or by contact with a platinum wire approaching incandescence.

* Eyre & Spottiswoode, London, 1889, 30 pp.

The 'fireworks' test makes a striking lecture experiment, especially the one devised by Mr. Redwood with 'vesuvians,' or incandescent cigar lighters. For this purpose he attaches two, of the glowing variety, to a wire so that the tip of one will be in contact with the base of the head of the other. The latter is lighted, and when it ceases to flame, and only glows, the mass is thrust into the explosive mixture, where it remains with the combustion, progressing from tip to base and base to tip without other effect until, when flame bursts from the tip of the second vesuvian, the vaporous mixture surrounding it is ignited and an explosion ensues.

Col. Majendie has properly called attention in this report to the fundamental distinctions between the danger arising in the transportation of a cargo of dynamite and one of petroleum spirits, since in the former case an explosion does not take place until fire is brought to the dynamite, while in the latter case the dangerous vapors will travel to a fire at a considerable distance and even through intervening bulkheads.

For this reason mixed cargoes of which volatile inflammable liquids and explosives constitute a part are particularly dangerous, as was long since shown in the explosion of the canal boat 'Tilbury,' in Regent Park, in 1874, having on board five tons of gunpowder and four barrels of benzoline and also having a small fire burning in the after cabin some 35 to 40 feet from the forehold in which the petroleum was stored. Notwithstanding that the cargo was covered with tarpaulins and that there was an intervening bulkhead, the vapors reached the fire and a most devastating explosion followed. The cargo was thus made up in spite of a similar disastrous experience from similar causes on the 'Lottie Sleigh,' at Liverpool, in 1864,* and neither of them have proved a sufficient warning to alto-

* Abel, *loc. cit.*

gether prevent subsequent reckless disregard of all dictates of common prudence.

Yet, because of these experiences, attempts have been made in some instances, where small lots of spirit were taken by vessels, to avert disaster by carrying them as deck loads, but the experience on the 'Solway,' which carried 24 barrels of this article on the main deck before the poop, shows that this does not ensure security, for, meeting with heavy weather, the casks broke adrift, their vapors reached the galley or cabin fires, and the vessel, with 19 persons, was lost.

Even where great precautions are taken to prevent accidents they not infrequently occur from inflammable substances being met with in unexpected places, or being introduced surreptitiously in admixture with harmless bodies. Nowhere, perhaps, is more care taken in this respect than on passenger steamships and in the naval service, yet 18 years ago a series of accidents occurred on board English ships, the cause of which was for a time veiled in mystery and which, in the then-existing state of feeling consequent on the dynamite outrages, aroused the gravest apprehensions.

In June, 1880, a violent explosion took place, without any warning or apparent cause, in the forepeak of the Pacific Steam Navigation Co.'s steamer 'Coquimbo,' shortly after her arrival in Valparaiso. Several plates were blown out of the bow, and other structural damage was inflicted while the ship's carpenter, who was the only person apparently who would have thrown any light on the cause of the accident, was killed.

This explosion was followed on April 26, 1881, by a much more serious one on the man-of-war 'Doterel' (while at anchor off Sandy Point, in the Straits of Magellan), through which eight officers and 135 men lost their lives and the vessel was destroyed.

In May, of the same year, an explosion of trifling character happened on H. M. S. 'Cockatrice,' in Sheerness Dockyard; while in November one, which was sufficiently severe to kill two men, dangerously wound two more (one fatally) and injure six others, besides doing much damage to the ship, occurred on H. M. S. 'Triumph,' then at Coquimbo.

The first suggestion as to the real cause of these accidents was obtained in the investigation of that on the 'Cockatrice,' when it was developed that, just previous to the explosion, a man went into the store room with a naked light which he held close to a small can, that was uncorked at the time, and which contained a preparation recently introduced into the naval service (as a 'drier' for use with paint) under the name of Xerotine Siccative, and that this largely consisted of a most volatile petroleum product. As it had been issued without knowledge of this fact, instructions were at once sent out by the Admirality directing that it should be stored and treated with the same precautions as turpentine and other highly inflammable liquids or preparations; and these instructions had but recently reached the 'Triumph' when the accident narrated happened to her. Inquiry here developed the fact that the explosion originated in the paint room through bringing a lantern to a compartment in which a leaky can of Siccative had been stored, and following up this clue the explosions on the 'Coquimbo' and 'Doterel' were fully and definitely proved to have been due to the presence on board of this same substance; while experiments with the material showed that it was capable of producing all the destructive effects observed, except, perhaps, in the case of the 'Doterel,' where, from the two reports noted and the other resemblances to the Regent Park explosion, there was but little doubt that the powder magazine was also exploded.

Such accidents were not, however, con-

fined to British vessels, for on October 13 1891, while the U. S. S. 'Atlanta' was going to the rescue of the wrecked 'Tallapoosa' an explosion occurred on the 'Atlanta,' which caused her immediate return to New York. I was at once ordered by the Secretary of Navy to proceed to New York and investigate the accident.

I learned that while the 'Atlanta' was laboring in a heavy sea she sprung a leak through the hawse pipes and the forward collision compartment began to fill with water; that a handy-billy was rigged to pump the compartment; that about midnight the suction pipe became plugged, and that on lowering a common lantern into the compartment an explosion ensued, severely injuring two men, slightly injuring four others and bulging the steel collision bulkhead. I found that the collision compartment had been used as a store room for paints; that among them were spar and damar varnishes and Japan dryer, each of which gave off inflammable vapors at ordinary temperatures; that the packages were sealed in a very insecure manner, and that, as this compartment filled and the vessel tossed, the cans were opened and their contents churned up so as to readily form explosive mixtures with the air.

I learned further that on June 15th previous a fire and explosion had taken place on board the U. S. S. 'Philadelphia' in close proximity to her powder magazine, and that another had occurred on the U. S. S. 'Bennington,' all being evidently due to the same material.

But notwithstanding these vigorous lessons the tale continues, and on April 14, 1896,* a 'petroleum accident' occurred on board the Cunarder S. S. 'Servia' when a party of men were engaged in painting the inside of a water-ballast tank. The tank, which was 3 feet 6 inches deep, was divided into 16 compartments, with 18 inches aperture between each. The farthest compartment was being painted at the time, and it was necessary to crawl through 15 of the small apertures to reach it. The paint used was styled Patent Bitumastic Solution, and one of the survivors testified that it took him four or five minutes to reach the compartments, ten minutes to do the painting, and four or five minutes to return, and that he could not stoop down any longer, as it made him dazed and queer in his head. All the witnesses testified that the use of the solution in confined spaces made them drunk and delirious if they remained any length of time at work. This is a well-known effect of the lighter petroleums, and it is not surprising that the solution was found to consist of coal tar dissolved in crude oil, having a flashing point of 45° F. Abel, and containing so much volatile matter that one gallon spread over a large surface would render 48 cubic feet of air inflammable.

Notwithstanding this the workman went into this inner compartment, which was already partly covered with the freshly-laid solution and containing a partly-filled bucket of it, with a lighted candle. Some time having passed without hearing from him, another workman went to his assistance and found the place on fire and the man burned and delirious. He was so delirious as to fight against coming out, and it took an hour and a-half with assistance to get him through the apertures and up the manhole, and he afterwards died in the hospital from the effects of the disaster.

Even while writing this we learn from the local press that a fire, preceded by an explosion, due to the use of Bitumastic Solution, occurred at the Central Market House, Washington, D. C., on November 16, 1898.

The notorious 'Hair Dresser's Accident' of June 26, 1897, through which Mrs. Samuelson was fatally injured in London, by the ignition of a petroleum hair wash

* Rept. H. M. Insp. Exp. **21**, *53;* 1897.

which was being used as a shampoo, illustrates anew the manifold uses to which these hydrocarbons are being put, and it brought out strongly the belief of competent authorities, like Lord Kelvin, that these substances could be ignited by frictional electricity; a theory which had been offered before in explanation of accidents in which there was no other apparent source of ignition.

The widespread distribution of these spirits in the hands of retailers, or as used for carburetters in isolated vapor-lighting plants and as employed in the arts for solvents, cleansing agents and for other purposes has led to their accumulation, through leakage or by being discharged after use, in low places, such as cellars, cisterns, wells, sewers and the bilges of ships, where they have remained, in some instances for long periods of time, unknown and unnoticed, their origin even being completely forgotten and untraceable, until, when, in the course of events, these out-of-the-way places have been reentered, these bodies have given rise to accidents. It is a well-known precaution of the past before entering a well or cave to test its atmosphere for carbon dioxide by means of a naked candle, but this very method of procedure has, since the introduction of petroleum, been the cause of accidents, and to be assured of security we must now remove and test the air before entering.

The extended consumption of naphtha for carburretting water gas, and the ease with which it is conveyed through pipes, has resulted in the use of systems of pipe lines in our cities to carry the oil from the transportation lines or store tanks to the works. Such a line was laid in Rochester, New York, and on December 21, 1887, it gave rise to an explosion which killed three men, seriously injured twenty, destroyed three large flour mills, tore up the streets for a considerable distance and inflicted an estimated loss of $250,000. This pipe line, which was made of 3-inch wrought-iron pipe, one and one-half miles in length, had been in successful use for six years, the spirits being pumped through it every two weeks in lots of from twelve to fifteen thousand gallons each. From the Appeal Book *in re* Ann Lee *vs.* The Vacuum Oil Co., Rochester, 1889, we learn that the conveyance of the naptha was complete on December 7th; on December 8th the contractors constructing a sewer exposed a section of the pipe line for several feet, and in blasting beneath it a piece of rock struck the pipe with sufficient force to bend it up nearly nine inches at the point struck and to separate it at a joint farther on underground and closely connected with a sewer; that on the day fixed for the next delivery, December 21st, the Oil Company, being unaware of the then-existing conditions, pumped the full supply into the pipe, none of which reached the gas works, but, on the contrary, found its way, by the broken joint, into the sewers, and was thus distributed over the city; that the pumping of the oil began at 12:15 p. m.; the odor was noticed shortly after 1 p. m., coming from a sewer at a point nearly a mile distant from the break; the first explosion occurred at this point at 3:20 p. m., and immediately extended westward back to the break and eastward to the outlet of the sewers, tossing up manhole plates, uplifting roadways and overturning buildings; that the explosive mixture was ignited by a fire under a steam boiler, and that this vapor found its way from the sewer to the fire through an untrapped water closet at a point where exhaust steam was being injected into the sewer.

At the trial, Mr. F. L. King, p. 173, stated that crude naphtha, flashing point 13°F., percolated through earth six times as fast as water at the same temperature, his several experiments being made with tem-

peratures varying for the liquids from 38°F. to 60°F. and for the earths from 32°F. to 60°F. Mr. George B. Selden, p. 178, found the mixture of naptha and air in the best proportions, to give, on explosion, a pressure of 140 pounds per square inch, while coal gas and air in the best proportions gave 160 pounds per square inch, and that the ignition point of the naphtha mixture was 950°C. while that of the coal gas mixture was 800°C.

I have already referred to the means taken for ensuring the removal of the more volatile hydrocarbons from domestic kerosene, a subject which has been very exhaustively treated by Rudolph Weber.* It has, however, been seriously stated that the lighter oils, such as benzoline or naphtha, might be rendered safe for use in lamps by adding alum, sal ammoniac or camphor to them, and many innocent persons have suffered in consequence of their belief in the efficacy of these substances. Some years since† I tested the effect of these bodies by determining their solubility in benzoline, the flashing points of benzoline and commercial kerosene when treated with these bodies and when in their original state, and also the readiness with which mixtures of the oils, in the two conditions, with air could be exploded. The results showed that alum and sal ammoniac were practically insoluble in the oils and produced no effect whatever upon them; that the camphor was soluble, one gram of benzoline dissolving about 1.5 grams of camphor; that an equal weight of camphor raised the flashing point of a kerosene 12°; but that, on the other hand, the vapor of this camphorated kerosene, when mixed with air, had a lower point of ignition, and hence exploded with greater readiness than the original kerosene.

What is true regarding the use, storage and transportation of petroleum products holds for other easily volatile liquids. Professor Thomas Graham, in his report* on the cause of the loss of the 'Amazon' on January 4, 1852, pointed out clearly the danger in transporting turpentine, while the destruction of the 'Livadia,' of Liverpool, May 11, 1891, carrying a cargo of carbon disulphide, emphasizes the hazard attending this substance, for this heavy and very mobile liquid gives off quite rapidly at ordinary temperatures a vapor which is 2.64 times heavier than air, and which not only readily collects at the bottom of any space in which it is produced, but follows in a stream like water.

One of the more striking characteristics of the mixture which this vapor forms with air is its low point of ignition. The tiniest spark; a cinder after it has ceased to glow, or the striking together of two pieces of iron without sparking, are sufficient to determine its ignition. This property may be exhibited by plunging a glass rod heated to 231° C., (450° F.) (a temperature at which it can be touched with the bare hand) into the mixture.

The use of ether, alcohol, acetone and aldehyde, with nitroglycerine and guncotton, for the manufacture of smokeless powders, and of the esters as solvents for pyroxylin in the making of the varnishes that are largely used in household decoration, are some of the more modern forms of hazard, while the explosion at the Hotel Endicott, in New York, and at Newark, N. J., indicate what may be expected from the more extended use of liquefied air and liquefied acetylene.

Although Dr. John Clayton, the Dean of Kildare, in the sixteenth century, effected the destructive distillation of coal and collected and burned the gas from it,† it was

* Ding. poly. J. **241**, *277 and 383;* 1881.
† *Proc. A. A. A. S.* **33**, *174;* 1885.

* Spontaneous Combustion and Explosions occurring in Coal Cargoes, Thomas Rowan, p. 40, 1882.
† Treatise on Coal Gas, William Richards, 1877.

not till 1792 that William Murdock devised the means for utilizing the substance and erected a plant at Cornwall, England, with which to light his house and office, and after several years of active agitation by the energetic promoter, F. A. Winsor, that in 1810 an Act of Incorporation was obtained for the London and Westminster Gas-Light and Coke Co., and the first installation on a large scale for lighting the streets of a city and supplying the public began, and through the ingenuity and resources of Samuel Clegg, the engineer, the devices were invented or assembled by which the practical manufacture, storage, distribution and use was successfully accomplished.

From this source the use of gas for lighting and heating extended over the world, reaching New York in 1834 and bringing in its train comfort and cheer, increased security, and added power to man, so long as the substance was confined to its proper channels and used in proper devices, but carrying also the possibility of working harm if the vigilance of its keepers was relaxed and it escaped from bounds; therefore beginning with the explosion at the lime purifier of the Peter Street Station, London, in 1814, through which Mr. Clegg was injured and two 9-inch walls thrown down, we have a vast army of explosive accidents originating in the ignition of mixtures of illuminating gas with air.

Owing to the circumstances attending some of these explosions there has arisen a vulgar opinion that illuminating gas is an explosive; in fact, in a recent case* counsel cited opinions of courts deciding 'gas' to be explosive; yet every chemist knows that it is not explosive *per se* and that it cannot even be made to ignite unless in contact with air or other supporter of combustion.

While we know the truth and may be able to demonstrate the fact, it is very satisfactory to be able also to cite the results of experience on a large scale; therefore the following from the *Journal of Gaslighting*, August 1, 1871, may be welcome. It appears that at the bombardment of Paris the Governor of the city feared that the gas holders of La Villette would endanger the fortifications. He was assured that there was not the smallest risk; that if a projectile penetrated a gas holder and set fire to the gas the latter would only burn out as a jet of flame, and that there could be no such thing as an explosion, since the constant pressure would effectually prevent any access of air. Shortly after a shell pierced the holder at Ivry and lighted the gas. There was a huge jet of flame for eight minutes; the holder sank slowly and all was over. At La Villette a shell penetrated a filled gas holder and burst in the interior without igniting the gas. At Vaugirard another shell entered, and again there was neither ignition nor explosion.

Many of the accidents from coal gas and its congeners, 'water gas,' 'producer gas,' and 'generator gas,' have been due to the escape of the gases from the interred pipes and mains from which they have reached sewers, cesspools, cellars and other enclosed places, for, though these gas conduits may be sound and tight when laid, leakage will in time be caused by the corrosive action of materials in the soil, by electrolysis, by fluctuations in temperature, by settlement in filled ground and by seismic changes.* The extent of this leakage from the mains in New York City was discussed in a Legislative investigation some nine years ago, and, while the Chemist and Health Department claimed that ten per cent. of the entire annual product or one thousand million cubic feet escaped, the gas companies' representatives denied that more than one hundred million feet were lost in each year.

* Proc. U. S. Nav. Inst. **22**, *638*; 1896.

* Milne, McClure's Magazine, **11**, *17–27*; 1898.

W. C. Holmes & Co.* give the allowed leakage as five per cent. and the average leakage as ten per cent., while H. Tobey, in his paper on 'Elusive Leakages from Mains and Services,'† which was warmly discussed by the gas association before which it was read, shows that the condition still exists, and he gives illustrations showing the danger consequent on leaving abandoned sewers in place.

Owing to the fact that Bunsen, Angus-Smith, Letheby and Durand-Claye found large quantities of methane, hydrogen sulphide, and sometimes carbon monoxide, in the gases from stagnant sewage decomposing under water, there has arisen a belief that 'sewer gas' is explosive. Simple consideration of the facts that such stagnation cannot occur in a properly constructed sewer, and that such a change does not take place in flowing sewage, is sufficient to cast doubt on the existence of such a gas. It has been completely shown by Professor Wm. Ripley Nichols, in his Chemical Examination of Sewer Air,‡ as the result of his own extended observations, and from the discussion of numerous data by other investigators, that sewer air differs from ordinary air only in containing a larger percentage of carbon dioxide, and that 'sewer air is neither inflammable nor explosive.' The air of vaults and cesspools is, of course, a different thing, as the material in these may become stagnant.

It was as early as 1819 that an English patent was granted to David Gordon and Edward Heard for compressing gas in strong copper or other vessels fitted with ingenious reducing valves for regulating its rate of emission; 30 feet of gas being compressed into a volume of one cubic foot, and gas so compressed in cylinders of two cubic feet capacity were conveyed to the houses of consumers, with which to operate an isolated plant. Sometimes the pressure was sufficient to liquefy the gas, and it is interesting to note that it was in the liquid from one of these reservoirs that Faraday discovered benzene.

Naturally the tension of the gas itself tends to rupture the receptacle, and many accidents from explosions of this nature have occurred owing to defects in the cylinders, or to the exposure of the filled cylinders to unduly high temperatures, or to shocks; a recent accident that could not be explained in any other way occurred at Albany, N. Y. on December 6, 1893.*

With the increased demand for compressed gases of various kinds under high tensions, such as carbon dioxide, sulphur dioxide, ammonia, chlorine, nitrogen monoxide, acetylene, air and others which are being used or introduced for commercial, scientific or domestic purposes, there is being developed a continued improvement in the strength and homogeneity of the cylinders, so that the danger from this cause is diminishing.

Although Dr. Robert Hare had invented his oxyhydrogen blowpipe in 1801,† yet in 1834 Gordon and Deville were granted a patent for their calcium or 'lime' light. It was expected by the projectors that this form of light would replace gas, as burned from ordinary burners, for lighting streets, and it caused the holders of gas securities much anxiety, but as we are now aware the device came to be used for geodetic, scientific and exhibition purposes only.

Where the gases stored in vessels are of an inflammable nature there is an additional risk to that due to the tension of the gas, since by admixture with air or oxygen an explosion occurs on ignition. One source of these accidents arises from the diffusion

* Instructions for the Management of Gas Works, p. 41, London, 1874.

† Am. Gas Light J. **64**, *767;* 1896.

‡ Rept. Supt. of Sewers, Boston, Mass., 1879.

* Proc. U. S. Nav. Inst. **22**, *638;* 1896.

† J. Am. Chem. Soc. **19**, *719;* 1897.

of one gas back into the reservoir of another gas, but this is entirely prevented by proper regulation of the pressure and size of the orifice. Another arises from confusing the cylinders when filling them, and to prevent this the cylinders have been painted different colors. Yet, as shown by the fatal accident described by W. N. Hartley,* this has not prevented the deliberate interchange of the cylinders under the pressing demands of trade, and the usual causalty has followed. Therefore, he proposes that the fittings for the two classes of cylinders be made so entirely different that it will be practically impossible to charge the cylinder with the wrong gas, and in view of the probable increased use of gas in this form, as indicated by Mr. Thomas Fletcher,† the change should be made. Yet I doubt if it will be, except under compulsion of law, for I have learned in my efforts to introduce safety explosives in this country that the great majority will not secure the assurance of safety if this entails a little inconvenience and the taking of a little more pains.

A more common source of accident has come from impurities introduced in the making of the oxygen, as, at Nahant, Mass., where pulverized stibnite was mistaken for pyrolusite, and mixed with the potassium chlorate. Limonsin describes an accident at Cannes in 1880, which attracted unusual attention from the factitious circumstance that the gas was being prepared for the Empress of Russia,‡ and found the cause in the evolution of hydrocarbons from the rubber connecting tube by particles of heated potassium perchlorate carried into it through the turbulence of the reaction. While Professor C. A. Young gives an account § of the explosion at Princeton while filling a steel cylinder with oxygen by means of a water-jacketed, steam force pump, and finds the cause in oil used for lubricating the pump being sprayed into the gas cylinder so as to form an explosive mixture with the oxygen. He recommends the use of soap suds as a lubricant in place of oil. Frankland* describes a similar instance and gives a similar explanation.

Recently my attention has been called to several accidental explosions of oxyhydrogen mixtures formed in the operation of storage batteries, the detonating gas being fired by the spark formed on breaking connections at the battery.

But of all circumstances under which explosions occur the most awful are those which so frequently happen in mines, for if the miner escapes instant death it too often is but to die from suffocation, or, worse yet, to be entombed and perish from starvation preceded perhaps by insanity.

It has long been known that fire damp found its way into coal mines, and in 1674 Mr. Jessop communicated to the Royal Society a description of the accident met with by Mr. Michel, who penetrated into the gallery of a coal pit, in Yorkshire, with a naked torch and was severely burned. It is interesting to note† that, when rescued, he declared he had heard no noise, though the workmen in the vicinity had been terrified by a tremendous report accompanied by a vibration of the earth. As is to be expected, from what we now know of natural gas, inflammable gases are not confined to coal mines, but, as shown by B. H. Brough,‡ they are met with in metalliferous mines and other excavations also.

The appalling nature of these catastrophes led to efforts being made to at least reduce their frequency, if not to prevent them altogether, an extended account of these being

* Chem. News, **59**, *75 :* 1889.

† 'On a New Commercial Application of Oxygen.' J. Soc. Chem. Ind. **7**, *182 ;* 1888.

‡ U. S. Nav. Inst. **14**, *167 ;* 1888.

§ Sci. Am., p. 369, June 11, 1887.

* Am. Gas Light J. **5**, *289 ;* 1864.

† Treatise on Coal Gas, Wm. Richards, p. 4, 1877.

‡ *School of Mines Quarterly* **12**, *13–22 ;* 1890.

given in Mining Accidents and their Prevention by Sir Frederick Abel, N. Y., 1889. It was early recognized that the presence of naked light was a constant source of danger, and hence the invention of the safety lamp by Sir Humphrey Davy, in 1816,* was hailed as a most beneficent gift of science, and this was soon followed by the lamps of George Stephenson and Dr. Clauny. When exposed but a short time in at atmosphere rich in gas and which is moving at a low velocity these lamps protected the miner, but if allowed to remain for some time in the gas-rich atmosphere the gauze becomes heated to the ignition point of the gas, from the gas mixture burning within it. By the introduction of ventilating appliances to remove the gas the currents of air in the mainways frequently reach a velocity of between twenty and twenty-five feet, and between two airways it may rise to thirty-five feet per second. In breaking down the coal the confined gas may rush out at a very high velocity, it being found by experiment at the Boldon Colliery that the gas may be under as great a pressure as 461 pounds to the square inch. And, finally, the air and gas may be set in motion at a high velocity by the firing of explosives to bring down the rock or coal, and more especially by a 'blown out' shot. Under such conditions the primitive safety lamps above described failed, but protected lamps have been invented which have resisted currents of even fifty feet per second for a brief period, though it is said that these are insecure in certain positions to which they may be tilted in practice, and that the glass cylinders are liable to fracture.

Instead of relying upon the safety lamps for protection a better method of procedure is to test the atmosphere of workings for the presence of fire damp before allowing the workmen to operate. Various methods have been pursued, and these are resumed in 'The Detection and Measurement of Inflammable Gas and Vapor in Air, by Dr. Frank Clowes, 1896, London,' and he there describes a very ingenious and efficient fire damp detector which he has devised. This consists of a simple and convenient hydrogen lamp by which one can detect 1/10 of one per cent. of methane or 25/100 of one per cent. of coal gas in air. He attaches a small steel cylinder (weighing about fourteen ounces) charged with hydrogen under 100 atmospheres of pressure to the side of a safety lamp, and leads the gas through a minute copper tube up beside the wick holder of the lamp, there being a reducing valve attached to the cylinder by which to feed the hydrogen to the lamp as desired in order to control the height of the flame.

The lamp is lighted as usual at the oil wick and covered; then, when the atmosphere which it is desired to test is reached, the hydrogen is turned on and ignited, the oil flame is pricked out, the hydrogen flame adjusted to a regulation height of 10 mm. and the flame observed through the chimney against a black background. If an inflammable gas be present it will produce a pale blue cap about the hydrogen flame, and the height of this cap will increase with the per cent. of the gas in the atmophere. By means of a scale on the chimney the height is measured and the per cent. determined.

In his experiments Clowes obtained the following:

LIMITING EXPLOSIVE MIXTURES OF VARIOUS GASES WITH AIR.

Combustible gas used.	Percentage of Gas in Air. Lower Explosive Limit.	Higher Explosive Limit.	Method of Kindling
Methane	5	13	Upward.
	6	11	Downward.
Coal gas Nottingham	6	29	Upward.
	9	22	Downward.
Water gas	9	55	Upward.
Hydrogen	5	72	"
Carbon monoxide	13	75	"
Ethylene	4	22	"
Acetylene	3	82	Downward.

* Trans. Roy. Sec. **106**, 1.

The lower 'limit' of inflammable gas represents the minimum proportion which, when mixed with air under ordinary conditions, will burn rapidly, and will, under certain couditions, produce explosions. If the proportion of inflammable gas mixed with the air is less than this in amount the mixture will only burn in the immediate neighborhood of the kindling flame, and will not burn throughout. If, on the other hand, the proportion of inflammable gas in the air exceeds the maximum 'limit' the gas will only be kindled and burn where it is in contact with an additional supply of air.

All proportions of gas intermediate between these limits are explosive when mixed with air, consequently the chance of an explosion resulting from the presence of one of these gases in the air is the greater, the more widely the 'limits' are apart, since this gives rise to the possibility of a larger number of explosive mixtures being produced. Therefore, the danger of explosion is least with methane and greatest with acetylene. Methane is a safer gas also because it has a high temperature and a slow rate of ignition. All of these condititions tend to lessen the number of colliery explosions. It is to be noted that mixtures that cannot be ignited when the flame is applied to their upper surface may be fired from below, and this is the method of firing most probable to occur in coal mines.

Few of the gases mentioned occur singly under conditions likely to give rise to danger. More commonly the combustible gases are present in a state of mixture, as in water gas and in coal gas.

In giving 'limits' it is assumed that the temperature of the mixture is not above 18°C. and that the pressure does not exceed 76 cm., for a gaseous mixture which is not inflammable under these conditions may become inflammable under increased temperature or pressure, and also that a mixture that by ordinary test appears uninflammable will propagate flame if a considerable volume of gas be projected into it, owing to the resulting increase in temperature and pressure.

It will be observed that Clowes' detector reveals the presence of gas in proportions much below the danger point and gives timely warning.

The ignition of the fire damp has been frequently caused by the gunpowder and 'straw' used in blasting, for the outbursts of gas from the shaken coal and the outrush of flame and incandescent particles from the blast were often coincident. The use of electric primers and detonators remedied entirely the evils following the use of straws and naked fuse, and the employment of the high explosives gave greater immunity by reducing the frequency of the blasts. Greater security still has followed the use of the flameless explosives made from nitro-substitution compounds, or dynamites in which crystalline salts, like sodium carbonate and alum, containing a larger amount of water of crystallization, are incorporated in the mass, or water cartridges, in which the explosive in the bore holes is placed in a water bag or surrounded by moss, or other porous substances, saturated with water.

The occurrence of these mining accidents has caused the authorities grave concern, and several of the European governments, notably Prussia, France and England, have appointed many commissions, some temporary and others continuous, to investigate the reasons for the accidents and the methods of prevention. Many of the most prominent chemists of these countries have been called to serve upon the commissions, and their reports have proved not only useful in the solution of the problem in hand, but have been valuable contributions to chemical science. One of the more recent consequences of

their deliberations is the establishment at Woolwich, England, of a station for testing all explosives offered for use in coal mines, and hereafter no explosives but those which successfully pass these tests can be used, and then only in the manner minutely described in governmental authorization.*

The closer study of the phenomena of explosions in gases, consequent on these investigations, has developed many interesting facts. Bunsen found that when mixtures of hydrogen and oxygen and of carbon monoxide and oxygen in equivalent proportions were inflamed the union went on by fits and starts, and that the velocity of propagation of the reaction, through narrow orifices, was 34 meters per second in the hydrogen-oxygen mixture, and but one meter per second in the carbon monoxide-oxygen mixture.† Mallard tested various mixtures of methane and air, and coal gas and air, in the same way finding the velocity of combustion to diminish rapidly as the proportion of inert gases present increased, and obtaining a maximum speed in the case of eight volumes of air to one volume of marsh gas of 0.56 meters per second.‡

Berthelot, using tubes of 40 meters in length and 5 millimeters in diameter, obtained velocities of 2,810 meters per second for hydrogen-oxygen, 1,089 for carbon monoxide-oxygen and 2,287 for methane-oxygen,§ and found that the reaction could be propagated in three different ways: First, by combustion, as observed by Bunsen, in which the heat evolved is being continually lost through radiation and conduction, and in which, consequently, the pressure is exerted by the layer of burning molecules on their adjacent molecules, and hence their velocity of translation tends constantly toward a minimum. Second, by detonation in which the heat evolved, the pressure produced by the reacting molecules on contiguous molecules, and the velocity of translation of the explosive reaction all tend toward the maximum. And, finally, an intermediate stage; all three being marked by distinct waves. Von Octtinger and von Gernet* have, by a very ingenious arrangement, succeeded in photographing, first, a fundamental one, which they style Berthelot's wave; second, more or less parallel secondary waves, whose existence they explain on Bunsen's hypothesis of the reflex action of waves due to successive explosions produced by the electric spark, and which they style Bunsen's waves; and third, polygonal waves of smaller amplitude. They obtained a velocity of 2,800 meters per second, which is of the same magnitude as those obtained by Berthelot.

Berthelot and Vieille's experiments show that when an explosion occurs in a gaseous mixture a number of ignited molecules are projected forward with a velocity corresponding with the maximum temperature produced by the chemical combination. The impact of these molecules causes the ignition of the adjacent particles, and the rate of progression of the combustion is thus dependent upon the activity of the chemical action.

Mallard and Le Châtelier find that the rate of propagation of flame through an inflammable gaseous mixture is affected not only by the temperature and size of the igniting flame, but also by the mechanical agitation or disturbance of the mixture itself. These results are not surprising when it is considered that for the spread of combustion in an inflammable gaseous mixture it is necessary that the temperature of the combustion should be sufficient to ignite the uninflamed portion.

* Rept. Com. to inquire into the History of Explosives for Use in Coal Mines, London, 1897.

† Ann. Chim. Phys. (4) **14**, *449*.

‡ Ann de Mines **8**, *1871*.

§ Sur la force de la poudre, **1**, **153**.

* Ann. der Phys.

Dr. W. H. Birchmore* has devised an apparatus for firing gaseous mixtures which shows many of those phenomena. He uses two large bulbs connected by a tube of determined dimension for his explosion chamber and a large tin foil condenser for igniting the mixture, and he finds the phenomena to be different from those observed in tubes ignited in the ordinary way. The reaction takes place more promptly and sharply, and when using hydrogen and air in variable amount not only is some of the oxygen ozonized, but hydrogen dioxide is produced with the water of the reaction.

When using acetylene, with sufficient air to consume it theoretically, some of the carbon is separated out in the solid form, although free oxygen was found in the residues, and it was not until he had reached eight times the volume of air required by the theory that he got the theoretical amount of carbon dioxide.

He also describes a form of experiment which very cleverly illustrates the successive phenomena occurring in the acetylene explosion at Paris.

The minimum volume of an inflammable gas which forms an explosive mixture with air is very considerably reduced if fine dust is present in the air. Buddle directed attention some 90 years ago, in an account of the Wallsend Colliery explosion, to the destructive effect produced by the ignited coal dust at a distance from the point of first explosion. Robert Bald, in 1828, pointed out† that the blast of flame from a fire-damp explosion might ignite the coal dust on the floor of the pit. Faraday and Lyell, in their report on the Haswell Colliery explosion of September, 1844,‡ demonstrated that coal dust may be instrumental in greatly extending and in increasing the disastrous effects of fire-damp explosions.

* Am. Gas Light J. **67**, 563-565 ; 1897.
† Ed. Phil. J. **5**, *101;* 1828.
‡ Inst. C. E. Tracts, vol. 284.

Abel* has shown that the presence of finely divided incombustible mineral matter in air containing less than 2 per cent. of fire damp causes the latter to become explosive on ignition, and Galloway has proved that a mixture of air containing less than one per cent. of fire damp can be made to explode when charged with finely divided coal dust. I have applied this observation of the effect of the dust in facilitating explosions to lecture experiments with inflammable gaseous mixtures.†

The explosion at the Capitol on November 6th was confined to that portion of the building known as the Supreme Court section and which joins the Senate wing to the central structure. In the center of this section is a dome which is rarely noticed, as it is completely overshadowed by the central dome of the Capitol. This dome is supported in the sub-basement on piers, while all about these piers are brick vaults and arches of varying heights, carrying the many partition walls and floors above them, and these, with those radiating from under the big dome and the connecting passages, form a perfect labyrinth. The complexity is increased by several of the spaces having been enclosed with brick walls so as to carry steam-heating coils and for other purposes. A large part of the wall space had been fitted with shelving, and these were filled to overflowing with pamphlets. One space was used as an engine room, from which to operate a Sturtevant blower that fed air over the coils. This engine was provided with a woven guard screen to protect passers-by, made from 5/16-inch wrought-iron rods, riveted on each edge into two wrought-iron bars, each of which was 7/8 inches wide by 7/16 inches thick. Directly opposite this screen and leading south was a low, narrow passage that opened into one of the largest and highest of the vaults, in which was stowed, in the open spaces be-

* Accident in Mines, Proc. Inst. Civ. Eng., 1888.
† Proc. U. S. Nav. Inst. **12**, *429;* 1886.

hind two supporting walls or piers, the ash from the wood fires which were burned in the rooms above. These hickory ash pits, as they were styled, were south of and directly in line with the passage leading toward the iron screen. This series of compartments was on the extreme west of the sub-basement. A few of the exterior compartments of the sub-basement received a very little daylight, but all the rest was wholly dependent on artificial light and several gas jets were kept constantly lighted. In the center of the sub-basement, under the dome, was a large gas meter connected to a 4-inch main and having on its outlet end a 200-light glycerine gas governor. This meter had not been in use for some time, and the inlet valve was closed, but the outlet valve was open, and it was discovered afterwards that this outlet pipe was also connected with a live 4-inch main. The explosion occurred about 5:15 p. m., and its effects were observed over 47,000 cubic feet of the basement and upward quite to the dome. By the explosion the brick arches, covered with earth and then with heavy stone pavement slabs, were torn up, brick partitions and supporting walls were overthrown, stout locked doors on the upper floors were torn open, and there was a general wrecking of all the lighter structural parts. Observation of the lay of the wreckage showed conclusively that it radiated in all directions from a point about the gas meter, and that the most violent effects were in general at the points most distant from this center. The most violent effect of all was on the west, where the heavy granite screen wall forming the façade of the building was displaced by $1\frac{1}{2}$ inches, and the stout wire protecting screen about the engine was forced into a depth of two feet from the original plane for an area of three feet in diameter, and many of the stout rods were ruptured. Searching examination showed that no explosive or other explosive-forming material than illuminating gas could have been present; that for thirty minutes prior to the explosion there was for some reason a gas pressure of twice the normal; that under an excessive pressure gas would flow through the governor, and that this could furnish sufficient gas to do the work accomplished

The gas had a specific gravity of 0.601, and as it escaped it flowed through the devious passages and compartments, filling first the pockets with mixtures of various proportions and settling lower and lower until the stratum reached down to the level of the burning gas jets where it was fired. These were near the meter, where, of course, the gas would be richest. Here was the region of combustion. As the tongue of flame rushed under the low archways and through the passageways to the higher vaults beyond, it produced a violent disturbance of the atmosphere, thoroughly commingling the gas and air and throwing a mass of inflamed gas into their midst, thus producing a greatly accelerated combustion and explosion. When this tongue of flame burst into the compartment containing the hickory ash this dust was also intimately commingled with the gas-laden atmosphere, and here was produced the most violent of all the effects manifested; for the granite screen wall that was displaced was on the right side of the hickory ash pits, and the stout wire screen that was perforated was directly in front of them and at the end of the low and narrow passage leading from the vault containing these pits; and further the most violent effects produced on the upper floors, quite to the top of the building, were about the spiral staircase leading from the compartment containing the wire screen and which was but a continuation, through the low, narrow passages of the compartment containing the hickory ash.

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II.

A Case of Egg Within Egg. F. H. HERRICK.

A SMALL egg of the fowl, measuring 21 by 17 mm., was taken from the yolk of an apparently otherwise normal egg. The included egg possesses a hard shell, shell membrane, albumen and yolk. Various kinds of inclusions belonging to this type have been recorded in the domestic fowl due to fusion of two egg-like bodies in the oviduct of the hen. Small eggs of this character are sometimes laid. They sometimes contain albumen and no yolk, and probably never have a blastoderm. The idea has already been expressed, and is apparently well founded, that the small egg represents the fragment of a normal egg which was ruptured and threw off a part of its substance at the time of leaving the ovary, such fragments being treated in the oviduct like full-sized ova.

Secondary Abdominal Pregnancy with Histolysis of the Fœtus. F. H. HERRICK.

THE case reported occurred in the cat, where rupture of the uterus, leading to intra abdominal birth, had resulted in the following conditions: (1) Abnormal development of peritoneal structures (thickenings, adhesions, fenestration of the membranes, and tag-like outgrowths over them); (2) fragmentation of the fœtus, and attachment of the parts to the omenta by overgrowth, the result of extensive proliferation in the constituent cells of these membranes; (3) the more or less complete replacement of the soft embryonic tissues by the proliferating cells.

On the Early Development of Cerebratulus. W. R. COE.

THE processes concerned in the maturation and fertilization of the ovum of *C. marginatus* agree closely with those which have been described by Kostanecki and Wierzejski for *Physa*, and by Child for *Arenicola*.

The centrosome arising from the spermatozoon divides early. The division of its aster is accompanied with the formation of a delicate central spindle. The sperm-asters eventually degenerate, although their rays often remain even after the cleavage-asters have appeared. Their centrosomes usually become lost to view. Occasionally, however, it can be demonstrated, with a good deal of certainty, that they do not actually end their existence, but retain their identity and become the centers of the cleavage asters.

The centrospheres of the cleavage asters increase enormously in size. They are not artifacts, for they may be seen in the living egg. The centrosomes are very minute. They divide early, and the asters of the second cleavage begin to form about them quite within the body of the centrosphere, as in the *Thalassema*.

The eggs of *Micrura cæca* and *Cerebratulus leidyi* furnish almost ideal examples of the regular spiral type of cleavage. The first two cleavages are almost exactly equal in size. In the third division the upper four cells are slightly *larger* than the lower four. A very regular blastula results. The marked backward inclination of the enteron is evident from the very beginning of gastrulation.

At the end of the first day the enteron becomes divided into two distinct regions. Pseudopod-like processes of cells grow out to separate the two cavities and almost completely. The posterior blind sack of columnar cells is not definitely cut off from communication with the exterior, however, and food may enter by a temporary opening between the cell-processes.

Large cells of the larval mesenchyme, which wandered into the segmentation cavity at the beginning of the gastrulation, multiply rapidly and arrange themselves in certain definite positions, as in *C. lacteus*. Most of them send out branching and

anastomosing fibrous processes, which become attached to the adjacent wall of the body, or of the enteron, to form the larval musculature. The others remain as parenchyma cells.

Fission and Regeneration in Cerebratulus. C. B. WILSON.

FOR three years, while investigating the embryology of *Cerebratulus lacteus*, Verrill, very few perfect specimens were found at the close of the breeding season, while there were many with regenerating papillæ. Last summer a perfect male and female were secured and kept for ten weeks. The genital products were discharged simultaneously three different times at intervals of several days. Then both worms dismembered the posterior half of their bodies without provocation.

The anterior fragments at once regenerated, growing in three weeks' time papillæ measuring 50 mm. in the female and 38 mm. in the male. The posterior fragments lived ten days and died without any signs of regeneration. But others have been kept alive several weeks under less favorable conditions and have yielded perfectly healthy sexual products. We are led to conclude, therefore, that *Cerebratulus* often dismembers voluntarily at the close of the breeding season, but, while the anterior fragments regularly regenerate, the posterior ones seldom if ever do so. Careful anatomical examination shows that actual fission is accomplished chiefly by means of the transverse muscles of the body-walls. There are no indications of the rows of nuclei found by Blenham in *Carinella*.

Sections of papillæ show that in regeneration the longitudinal muscles contain numerous transverse fibers; in the early stages the two kinds are about equal.

The large lateral nerve cords are regenerated from ectoderm cells. Two parallel longitudinal invaginations appear on the ventral surface of the papilla. The ectoderm between them contains no gland cells: a shallow longitudinal groove soon separates this ectoderm into halves. In the center of each half nerve fibers are formed from modified ectoderm cells.

They then migrate to their normal position, while both groove and invaginations quickly disappear and the ectoderm becomes filled with gland cells.

The Female Genital Tract in Melophagus. H. S. PRATT.

MELOPHAGUS OVINUS, a dipterous insect, is peculiar because of the unusual length of its uterine life, the young animal being born as a fully grown larva. This long uterine life has been the cause of a profound modification of the entire genital tract. The uterus is unusually large; two pairs of glands pour a milk-like food into the uterus which feeds the growing larva; the proximal portions of the oviducts are fused and function as a permanent receptaculum seminis; the ovary possesses a very thick peritoneal covering composed of branched muscle and connective-tissue fibres which forms a sac and encloses the two ovarioles; these are composed each of two follicles and a germarium, no terminal thread being present, and are attached by the germarium to the inner distal surface of the peritoneal sac, their lower ends hanging free within the sac. There are thus in the two ovaries at any one time eight follicles, each containing a developing ovum. A single egg is produced every two to four weeks; it passes into the uterus, being fertilized on the way, and there remains two to four weeks until the young animal is born, an old larva. The two ovaries, and within each ovary the two ovarioles, alternate in furnishing the next egg.

Intracellular Differentiations in Gland Cells of Phascolosoma Gouldii. MARGARET LEWIS NICKERSON.

IN the epidermis of this Gephyrean are

found several well-marked forms of epidermal organs, one of which is characterized by the presence of intracellular sacks or ampullæ leading into anastomosing canals. Such organs contain both sensory and glandular cells, but in the gland cells alone are found the intracellular sacks.

These organs present several well-marked conditions corresponding with different stages of functional activity. One suggestive condition shows the following details of structure. In the upper part of each gland cell are two sacks lying one within the other and separated by a considerable space. This intervening space is traversed by many delicate filaments connecting the walls of the two sacks. The inner sack becomes continuous at its outer end, with a narrow canal, while the outer sack is continuous with a sheath surrounding this canal. The several canals unite to form larger canals, and there finally results one main duct opening to the exterior. This duct is surrounded by a broad sheath, which is a continuation of the sheaths enveloping the ampullæ and primary canals. By the side of the main duct, within its enveloping sheath, is a large nucleus surrounded by a clear area, which probably represents a vacuole. Regarding this nucleus the ampullæ, canals and sheaths the following hypothesis is offered. The sheath of the main duct and its branches, including the radial vesicles surrounding the ampullæ, together constitute a cell of very irregular shape, a cell which in form may be compared to a bunch of grapes with its stem. This single cell contains the main duct, its branches and their terminal ampullæ, and itself reaches down flask-shaped processes containing the ampullæ, which are embedded in the outer ends of the surrounding gland cells. The walls of the outer sacks, and their continuations as the outer wall of the sheath, represent the boundary of this highly differentiated cell.

The Development of the Adhesive Organ of Amia. Jacob Reighard. (Presented for Miss Jessie Phelps.)

The adhesive organ of *Amia* consists of a pair of semicircular or sausage-shaped ridges forming together an incomplete ring on the end of the snout of the young larva. Each ridge is a row of six to eight epithelial cups which open on the surface of the snout. Their cells secrete a mucus by means of which the animal attaches itself.

The organ is formed in a very early stage as a diverticulum of the fore gut. This diverticulum subsequently divides into two, each of which continues to communicate for a time with the cavity of the foregut.

Each of the two diverticula later separates from the foregut, becomes elongated and curved into the form of a semicircle and divides into from six to eight closed vesicles. The vesicles finally open to the exterior and are thus converted into cups.

After being functionally active for a time the organ is pushed beneath the surface by the thickening ectoblast, becomes infiltrated with leucocytes, and finally disappears (larvæ of 20 to 25 mm.) without leaving any trace behind it.

The integumentary sense organs appear in the neighboring ectoblast, quite independently of the adhesive organ.

Dean's comparison of the cups of the adhesive organ with the integumentary sense organs is thus seen to be untenable.

Notes on Loxosoma Davenporti. W. S. Nickerson.

A pair of flask-shaped glandular organs is commonly present in the American species of *Loxosoma*, attached by their broader rounded ends nearly opposite the lower end of the stomach, one upon each side. Each consists of a central core of 4 or 5 glandular cells and a peripheral layer of flattened epithelial cells continuous with the epithelial body-covering of the animal. The gland

cells have basal nuclei and cytoplasm filled with fine granules; their distal ends extend outward to a minute pore at the extremity of the flask. After the discharge of their contents the central cells appear shriveled, and it is probable that the whole organ is soon afterwards lost. Individuals lacking one or both flask-organs are frequently observed. After being lost, the structure is reformed in the same position. It arises as a conical thickening of the ectoderm, of which the central cells take on a glandular function, and the lateral ones form the epithelial covering. Similar organs have not been described as occurring in any other endoproct. The function of their secretion is unknown.

On the outer surface of each tentacle just at the margin of the lophophore there is a single large cell which forms a slight protuberance. Its nucleus is large and situated near the deeper surface; the cytoplasm shows a number of delicate lines extending through it perpendicularly toward the free surface, which is covered by a thickened portion of the cuticula, having the form of a flattened disk or of a saucer with its concave surface outward. The observation of the living animal shows that these structures are unicellular suckers or organs for attachment by means of which the little creature fixes itself by the margin of its expanded lophophore while changing the position of its foot attachment.

The reproductive system of *L. Davenporti* presents the rare condition of proterogynic hermaphroditism. Both kinds of sexual products arise in the single pair of gonads, the ova being formed before the sperm. The evidence for this consists in finding in the same individual a functional ovary on one side of the body, while the gonad of the other side contained, together with an evidently degenerating ovum, a mass of cells showing various stages of spermatogenesis up to the mature spermatozoa with tails. Animals which are functionally males are relatively few during the summer months.

Buds remain attached to the parent till well matured. They vary in number from 1 or 2 to 12. Abnormal buds lacking tentacles, digestive organs, reproductive system, etc., are not infrequently present. They consist of a small rounded body borne on a slender stalk. The proximal side of the lophophore margin forms a blunt projection against which the rest of the margin can be opposed, thus closing the atrial cavity. The epithelium lining the atrium is composed of large glandular cells. The relation of these buds to the parent is not different from that of the normal buds, nor does their attachment persist longer. They appear to be incapable of leading an independent existence and have no known function. They are probably manifestations of a tendency to produce modified members of the colony comparable with the avicularia of certain Ectoprocta, a tendency derived from stock-building ancestors and which has not yet been eliminated. According to this hypothesis we must regard the non-colonial habit of life of *Loxosoma* as secondarily acquired, perhaps in adaptation to its semi-parasitic or commensal mode of life, not, as has been assumed heretofore, as a primitive condition.

Embryos are present, attached to the 'mammary organ' of the parent during July and August. On the embryo a pair of buds arise very early and are fully formed by the time it becomes free from the parent. Soon after the buds separate from it the embryo perishes without undergoing a metamorphosis.

On the Motor Reactions of Paramecium. H. S. JENNINGS.

THE paper was an analysis of the mechanism of reactions to stimuli in the ciliate infusorian *Paramecium.* To all classes

of stimuli *Paramecium* responds with the same motor reaction, in greater or less intensity. The direction of motion after a stimulus is determined by the structure of the animal's body and has no relation to the localization of the stimulus. *Paramecia* are not directly attracted by any agent; they collect in the regions of certain conditions merely in virtue of the fact that these conditions cause no motor reactions, while the surrounding fluid causes a motor reaction that results in random movements, which must (through the laws of chance) eventually bring the animal into a region where these motors cease.

Phototaxis of Daphnia. C. B. Davenport and F. T. Lewis.

The problem is to determine the dependence of the degree of phototactic sensitiveness upon preceding conditions of illumination. Other conditions being similar, do *Daphnia* reared in the dark respond to a fainter illumination than those reared in the light? Special apparatus afforded a quantitative answer to this question. *Daphnia* reared in half-darkness moved, on the average, nearly three times as far toward a light of about minimal intensity as did *Daphnia* reared in the light. We may conclude: Those individuals reared in the dark have become attuned to a lower intensity than those reared in the light.

The minimum intensity inducing phototaxis was, in the more sensitive *Daphnia*, 0.002 candle power at a distance of 3.5 meters, or $\frac{0.002}{3.5^2} = 0.00016$ meter candles. The phototropic sensitiveness of *Daphnia* is quite equal to the phototropic sensitiveness of the most sensitive seedlings.

Early Development of Pennaria Tiarella. Chas. W. Hargitt.

The egg of *Pennaria* is of relatively large size and heavily yolk-ladened. In color it is of a light orange or pinkish hue. It is of ectodermal origin and grows by an active absorption of other ovarian cells. The egg is discharged almost immediately upon the liberation of the medusa, which takes place during the evening from seven to ten o'clock. Fertilization occurs very soon after the egg is discharged, or possibly in some cases before, since in many specimens the medusæ are never liberated, and the eggs seem to be discharged with difficulty and not infrequently exhibit segmentation phases while yet within the bell of the medusa. But so far as I have been able to note, the sperms always gain access to the egg from the outside.

The extrusion of the polar globules is only rarely to be noted, but occurs in an altogether normal way. Segmentation begins usually within fifteen minutes of the access of the spermatozoon. The first cleavage is usually into fairly normal two-celled forms, but seldom exactly in the same way, perhaps no two eggs exhibiting the same cleavage features. This is peculiarly the case in all the later phases. It is absolutely indeterminate and remarkably irregular and erratic. So much so was this that during the first series of observations the whole lot were discarded, as probably for some unknown reason abnormal or pathological. A second series taken the next night behaved in the same way, and while still thought to be somewhat abnormal were followed through to the completion of the irregular cleavage, and were found the following morning to have become perfectly normal planulæ.

That they were genuine cleavage phenomena was conclusively proved by sections of the various stages and the demonstration of mitotic figures in all phases of growth and decline.

Somewhat similar though incomparably less marked phenomena had been noted long ago by Wilson in the development of *Renilla*, and by Metschnikoff in *Rathkea* and

Oceania, and, incidentally, by Bunting, in *Hydractinia*. The most nearly comparable observations, so far as I have been able to discover, are those recently reported by Andrews in *Hydra*.

This work was begun at the Marine Biological Laboratory in 1897, continued during 1898, and is still in progress. It is hoped that a fuller account, with definite illustrations, may soon appear.

Grafting Experiments upon Hydromedusæ. CHAS. W. HARGITT.

IN course of previous work upon regeneration among the Hydromedusæ, the problem of grafting was forcibly impressed upon me, and during the summer of 1898, at the Marine Biological Laboratory, was undertaken and followed up during nearly two months, and with results as briefly outlined below.

It was undertaken to show the practicability of uniting sections of different individuals, different species and even genera.

The first work undertaken was upon Hydroids, chiefly Tubularians, *e. g.*, species of *Eudendrium*, *Pennaria*, *Parypha*, *Clava*, with only one series of experiments upon a Campanularian. The latter was for some reason almost wholly negative in results. In all the former the results were unusually successful, no less than 10% responding within the limits indicated. To merely summarize:

1. No difficulty was found in securing perfect union between segments of the same species in from twelve to twenty-four hours. A delicate sheath of perisarc overlapping the proximal ends was first secreted, and this was followed by organic union of the cœnosarc of the hydroid. The grafting was equally successful whether made by oral, aboral or alternating contact of the segments. Abundant heteromorphism was secured along with the other results. 2. It was equally easy to secure union of male and female specimens of the same species. 3. If the distinctness of Agassiz's species of *Eudendrium dispar* and *ramosum* is to be maintained—a fact which has seemed to me doubtful—then there was secured a ready grafting of different species. 4. In no case was I able to secure successful grafting between different genera. This was tried repeatedly with several, but in each case with negative results.

The second problem undertaken was upon the medusæ. The most accessible form was *Gonionemus vertens*, and the results obtained were on this form alone. Grafting was made possible only by the expedient of paralyzing the specimens by emargination of the entire bell, thus removing the coordinating centers. This done, there was no more difficulty in securing perfect union of different portions of the body than with the hydroid forms. It mattered little from what portion of the body taken, or in what relation placed, perfect union was usually secured in from 24 to 48 hours. Two medusæ grafted orally recovered nervous activity, and even exhibited a definite coördination, the double medusa acting as one.

The Life-History of Dicyema. WILLIAM MORTON WHEELER.

A STUDY of the Dicyemidæ (*Dicyema coluber*, n. sp.; *Dicyemennea Whitmanii*, n. sp., and *Dicyemodeca sceptrum*, n. gen. et n. sp.), parasitic in the kidneys of the West Coast *Octopus* (*O. punctatus*), was undertaken with a view to answering the following questions concerning the life-history of these animals: 1. What are the relations of the nematogenic and rhombogenic individuals to each other? 2. What is the meaning of the so-called infusoriform embryo? 3. What is the meaning of the infusorigen? An examination of the parasites of one hundred *Octopus* of different ages led to the conclusion that the Dicyemidæ first reproduce as nematogens for several generations, but that

ultimately the same individuals become rhombogens and thenceforth produce only infusoriform young. Certain Dicyemids were found to contain both vermiform and infusoriform young. E. Van Beneden's view, that the infusoriform is the male Dicyemid, was confirmed by a study of its structure and a comparison of this form with the male Orthonectid (Rhopalura). From the fact that deeply staining bodies resembling the granules of the urn of the infusoriform, and probably for that reason spermatozoa were found among the germ-cells of the infusorigen, it was inferred that the infusoriform young may arise from fertilized ova, and that the infusorigen may be an adaptation for accumulating the germ-cells around a central cell to which the spermatozoa are also attracted, possibly by chemotaxis. It was regarded as probable that both the male (infusoriform) and female Dicyemid migrate into the kidneys of the young *Octopus* and there form colonies of nematogenic females before males are produced.

Notes on the Blind Fishes. C. H. Eigenmann.

1. There is a color pattern common to all the species of the Amblyopsidæ. This pattern is due to the arrangement of the chromatophores along the connective tissue septa separating successive muscle segments. The result is a series of longitudinal stripes where the septa are bent on the surface and a series of zigzag cross streaks. This pattern is best marked in *Chologaster agassizii*, in which but little color is present. It is somewhat obscure in *Chologaster cornutus* on account of the great development of pigment. It remains only as an arrangement of chromatophores in the blind members of the family where color is no longer present in sufficient quantity to be evident to the naked eye.

2. *Chologaster agassizii*, which has so far been known from the type only, was secured through a grant from the Elizabeth Thompson Science fund. It is a species with well developed eyes living permanently in caves. Its eye is notably smaller than that of the other species of *Chologaster* which live in open waters. The retina is very much like that of *C. papilliferus*, with thinner pigment layer. The eyes of the species of *Chologaster* show the following measurements:

C. papilliferus, 32 mm. long. Vertical diameter, .832 mm. Longitudinal, .880 mm.

C. agassizii, 39 mm. long. Vertical diameter, .720 mm. Longitudinal, .800.

C. cornutus, 32 mm. long. Vertical diameter, .960 mm. Longitudinal, 1.120.

Thickness of the retina of

C. papilliferus, 29–34 mm. long, .122 mm., 55 mm. long, .162 mm.

C. agassizii, 38 mm. long, .107 mm., 62 mm. long, .130 mm.

C. cornutus 27 mm. long, .73 mm., 43 mm. long, .83 mm.

3. The blind fish from Missouri is of different origin from the blind fishes east of the Mississippi. The details of this part of the paper have appeared in Science.

Regeneration and Regulation in Hydra viridis. Herbert W. Rand.

In a series of regeneration experiments upon *Hydra viridis* it was found that the polyps regenerate, on the average, fewer tentacles than are originally possessed. The more tentacles before regeneration the greater is the mean number after regeneration. Eight-tentacled *Hydras* showed the greatest reduction in the number of tentacles. Six-tentacled *Hydras* showed no reduction.

The average deviation from the mean was practically the same before and after regeneration. The average deviation from the mean after regeneration, and also the average deviation from the original number, was greater in the eight-tentacled groups and least in the six-tentacled.

The mean number of tentacles regenerated by whole six-tentacled *Hydras* was

6.0; by halves of six-tentacled *Hydras*, 4.6; by quarters of six-tentacled *Hydras*, 3.8. Of *Hydras* having the same number of tentacles the larger *Hydras*, or parts of them, regenerate more tentacles than the smaller ones or corresponding parts of them. *Hydras* cut longitudinally into pieces of equal volume, but bearing different numbers of tentacles, regenerate as many tentacles as are required to complete a normal number.

In the regeneration of a small fragment of hypostome with tentacles attached, one tentacle became thickened to form the body. Often in the regeneration of whole 'heads' a tentacle whose axis came to lie approximately in the axis of the body apparently became thickened to assist in the downward extension of the body.

In 'heads' severed immediately below the tentacles forms of very abnormal appearance resulted in the process of closing the wound. Abnormalities, consisting in tentacles abnormally placed and in unusual numbers of oral tentacles, persisted for a considerable period. Regulative processes resulted in the degeneration of abnormally placed tentacles and in the establishment of a normal number of oval tentacles. Tentacles but slightly displaced from the circumoval ring were shifted back into it.

The regenerative and regulative processes are directed toward the regaining of a perfectly normal form.

Notes on the Actinians of Bermuda. A. E. VERRILL.

On the Atlantic Palolo Worm. A. G. MAYER.

The Origin of Blood Vessels in the Chick. L. H. SNOWDEN.

The Evolution of the Color Pattern of Columba livia from that Preserved in C. affinis Blyth. C. O. WHITMAN.

BASHFORD DEAN,
Secretary.

STALACTITES OF SAND.

IN Mr. Rose's black-sand gold mine, on the Oregon coast, about fifteen miles south of Coos Bay, are some curious stalactites of sand which deserve attention on account of their exceptional character.

The mine is along an ancient beach about 160 feet above the sea level and nearly two miles distant from the present shore. The black sand in which the gold occurs rests directly upon the upturned and eroded edges of Tertiary shales. It is about 100 feet in width and four feet in thickness, and is overlain by about thirty feet of horizontal Pleistocene sand beds with some gravel. These have to be removed before the black sand can be reached. The black sand at this point is composed chiefly of garnet, with a number of other heavy ferromagnesian minerals. It is partially cemented by oxide of iron, but may be readily crumbled in the hand.

The gray sand by which the black sand is immediately overlain is composed chiefly of quartz, but contains also many grains of feldspar besides those of other minerals and rocks. In some places this gray sand is cemented so firmly as to form a friable sandstone, and when the black sand is removed from beneath the exposed under surface of the sandstones is found to be covered with stalactites of sand. The cross bedding in the sand dips gently to the west. The stalactites incline westward at the same angle, forming only a small angle with the surface to which they are attached. The forms of the stalactites are well developed; some are small, others nearly a foot in length. Most of them are single, but a few are double, as if two were united in their development. There is no sign of a tube down in the center, as in the case of many stalactites of carbonate of lime.

The cementing material by means of which the sand is held together, making these curious forms, is not soluble in acid.

In a thin section under the microscope it is seen that each grain of the sand is surrounded by a thin coating of crystalline quartz which fills the small interstices and binds the whole together.

It seems altogether probable that the solutions bearing silica followed the porous layers of sand in the cross bedding, but what determined its deposition through the sand in the shape of an icicle is not so easily understood. It is not impossible, although quite improbable, that wind erosion had anything to do in developing these forms. The stalactites exposed in the mine were not so situated as to be attacked by drifting sand. Their local character is scarcely less difficult to explain satisfactorily than the peculiar forms themselves.

J. S. Diller.

U. S. Geological Survey,
Washington, D. C., February 18th.

SCIENTIFIC BOOKS.

Degeneracy: Its Causes, Signs and Results. By Eugene S. Talbot, M.D., D.D.S. The Contemporary Science Series. London, Walter Scott, Limited; New York, Charles Scribner's Sons. 1898. Illustrated.

The busy reader who has dipped into the works of Morel, Lombroso, Nordau and other writers upon degeneracy, and who has become, perhaps, somewhat confused by conflicting opinions and sweeping applications of this interesting biological doctrine, will receive with delight this calm and dispassionate as well as condensed 'conclusion of the whole matter' (up to date). The plan of the book is good, giving as it does a brief survey of the whole subject from its historical, biological, psychological and pedagogical points of view. The author, too, is well prepared for his task, having a wide dental and medical experience, and, particularly, a most extensive acquaintance with the literature of the subject, especially of that literature which is most valuable here, viz., that of the medical and biological journals. This gives the book a healthy inductive tone. The author spends no time in the discussion of theories of his own or of others. He gives us rather a summary of facts relating to the antecedents and the symptoms of degeneracy in all its forms. Of the eighteen chapters some of the most interesting are the ones on heredity and atavism, consanguineous and neurotic intermarriages, toxic agents, school strain, degeneracy of the brain and degeneracy of mentality and morality. In the chapter on heredity and atavism the summary of the accumulated evidence against Weismannism is rather striking.

In a series of chapters the author discusses the causes of degeneracy. Among these, contagious and infectious diseases, led by tuberculosis, syphilis, typhoid fever, scarlatina, small pox, measles and diphtheria, are the most prolific. Other leading causes are toxic agents, such as tobacco, alcohol, opium, tea and coffee, insufficient or impure food and unfavorable climate, and, finally, school strain among children. The immediate consequence of these agents is nervous exhaustion in the first generation. The offspring of these neurasthenics do not possess the necessary vitality to carry them through the normal process of development. The result in the second generation is arrested development of the nervous centers and degeneracy of bodily structure, exhibited in the form of reversions to primitive types. Very full descriptions of the various stigmata of degeneracy follow. Among them are local reversionary tendencies, such as anomalies of skull, jaws, teeth, ears, etc.; nutritive degeneracy, shown in cancer, gout, goitre, adenoids, plural births and excessive fecundity; sensory degeneracy, such as deaf-mutism and congenital color-blindness; intellectual degeneracy, such as paranoia, hysteria, epilepsy, idiocy and one-sided genius; and ethical degeneracy, such as crime, prostitution, pauperism and inebriety. Degeneracy caused by alcohol is less dangerous to the community than that caused by opium and by various contagions and infections, since, owing to its deteriorating effects upon the reproductive organs, it tends to exterminate itself. This non-survival of the unfit is by no means true of all forms of degeneracy. Healthy atavism, however, is always at work and tends to counteract the immediate results of heredity.

Consanguineous marriages are not in themselves, in perfectly healthy stock, causes of degeneracy, but where degeneracy has begun, such marriages, of course, accelerate its action.

The book closes with a chapter on the prevention and treatment of degeneracy. The author is not an advocate of heroic methods, such as the legal regulation of marriage and other still more certain methods of checking its transmission. He proposes milder means, particularly rational forms of prophylaxis adapted to circumstances and to individuals.

G. T. W. PATRICK.

UNIVERSITY OF IOWA,
IOWA CITY.

A Synonymic Catalogue of the North American Rhopalocera. By HENRY SKINNER. American Entomological Society, December, 1898. Pp. xiv+100.

The catalogue of North American butterflies published by Mr. W. H. Edwards in 1884 listed 612 species from the United States and Canada. The new catalogue, now before us, enumerates 645; the moderate number of additions in about 14 years of great activity among lepidopterists indicates that our butterfly fauna is fairly well known. The additions are in reality somewhat more numerous than the figures cited indicate, owing to the rejection of some of the names of the earlier list; but there is no tendency to 'lumping' exhibited, which is rather surprising in consideration of some of Dr. Skinner's previously expressed views.

The literature is cited very fully, though we notice a few omissions, such as that of Edwards' account of the larva of *Lycæna exilis*. The genera are nearly as in the Edwards catalogue. It is to be regretted that *Pamphila* is still made to include a great number of forms, belonging to numerous genera; but it is certainly true that the best generic arrangement which could be offered at the present time would be largely provisional.

An examination of the catalogue recalls and emphasizes certain interesting features of our butterfly fauna. Certain portions are of tropical origin, while other groups belong to what has been called the holarctic region. In the tropics conditions have been relatively uniform for ages, and in consequence we have a large number of organisms in a condition of considerable stability—in other words, 'good species.'

The writer has found, when working with Coccidæ, that the tropical species are, as a general rule, much more easily separated than those of temperate regions. The same is true, apparently, among the butterflies. Take the Hesperidæ and Lycænidæ, which are so numerous in tropical America. The tropical groups of Hesperidæ, in particular, have largely invaded the United States, and very many species have been catalogued. Now Dr. Skinner himself has told us in another connection that these species are, as a rule, well-defined, though frequently superficially similar. But there is one characteristically holarctic series of Hesperidæ—the series of *Pamphila comma*—and here at once we meet with innumerable local races or weak species, with difficulty to be separated from one another. So in *Lycæna* the holarctic group of *pseudargiolus* and its allies is especially polymorphic. When we come to the typically holarctic genera, such as *Argynnis*, we find a wilderness of plastic forms, which may be called species or varieties according to the taste of the student.

It thus happens that for the evolutionist temperate regions, lately subject to glacial desolation, are in many respects more interesting than the luxuriant tropics. Here, especially, are species in the making; here is Nature's kitchen and the cook at work. In the tropics, on the other hand, we often find more numerous and more finished products, and wonderful adaptations, the origin of which is past our comprehension.* The naturalist in South America might well think species were created as he found them; the naturalist of the northern United States could hardly imagine such a thing, unless convinced on *a priori* grounds.

Yet when changes have occurred in tropical lands we find such phenomena as are common in the north. The snails of the Greater Antilles, islands that have undergone great changes of level in recent geological periods, are almost as confusing as the North American Argynnids. So, it seems, we may in some measure learn the

* For plants compare Dr. E. Warming's interesting paper in the *Botanical Gazette*, January, 1899.

past history of a group by studying its species. If the species are well defined and show elaborate adaptations to the environment the group has long existed under relatively uniform conditions. If, on the other hand, the species are defined with difficulty and connected by numerous races it may be presumed that the environment of the group has changed in recent times, and especially that it is undergoing expansion and differentiation in new territory. In northern regions the retreat of the ice has exposed much such territory; in the Antilles it has been the elevation of the land; in other cases a type may have found new lands by migration, and may thus exhibit incipient new species in the midst of a stable ancient fauna. As an example of the last-mentioned class may be mentioned *Danais berenice jamaicensis* in Jamaica, as against the old Jamaican type *Papilio homerus*. We have digressed from the immediate subject of this useful catalogue, but the interest of such works lies largely in the suggestiveness of their orderly and condensed array of facts.

T. D. A. Cockerell.

Mesilla Park, N. M., February 12, 1899.

Industrial Electricity. Translated and adapted from the French of Henry de Graffigny. Edited by A. G. Elliott, B.Sc. London and New York, The Macmillan Company. Pp. 152. With 65 illustrations. Price, 75 cents.

This little volume, according to the editor's note, is the first of a series upon Electro-mechanics, the other volumes of which will treat the more important of the branches here touched upon, separately and in detail. It is divided into short chapters, and explains, in very clear and non-mathematical language, the various applications of electricity.

Beginning with Nature of Electricity, a *résumé* of Hertz's work is given, showing the identity of light and electrical vibrations. Then follow, in order, chapters on Electric Units, Magnetism and Induction, and Practical Measurement of Electrical Quantities.

Chapters V. and VI. are respectively on Chemical Generators of Electricity and Accumulators, covering the subjects of primary and storage batteries and containing much useful information and explicit directions as to handling and care.

Dynamo Electric Machinery is next touched upon, including direct current dynamos, alternators, two- and three-phase generators. The remaining five chapters merely touch upon the following subjects: Electric Light, Electricity as a Motive Power, Electro-chemistry and Electro-plating, Bells and Telephones, and Telegraphs.

The only criticisms that can be advanced are:

1. On page 12 the table gives 10^2C.G.S. units in one Henry instead of 10^9, while the table on page 27 has many of the dimensions of the mechanical, electro-magnetic and magnetic unis given incorrectly.

2. Besides these lapses the volume is, with one or two exceptions, entirely devoid of allusions to American apparatus and machinery.

Taken as a whole, however, the volume is a creditable piece of work, for the task of condensing so much in so small a space is, to say the least, herculean. W. H. F.

GENERAL.

The Teachers' Professional Library, edited by Professor Nicholas Murray Butler, of Columbia University, is announced by The Macmillan Co. The books already published on 'The Development of the Child,' by Dr. Nathan Oppenheim; 'The Study of Children and their School Training,' by Dr. Francis Walker, and a 'Handbook of Nature Study,' by O. Lange, are included in the series and the following are announced for early publication:

'The Practical Lessons of History,' by William T. Harris, LL.D., U. S. Commissioner of Education.

'Social Phases of Education in the Home and in the School,' by Samuel T. Dutton, Superintendent of Schools, Brookline, Mass.

'Educational Aims and Educational Values,' by Dr. Paul H. Hanus, Harvard University.

'The Hygiene of the School and of Instruction,' by Edward R. Shaw, Ph.D., New York University.

'Method in Education,' by Walter L. Hervey, Ph.D., Department of Education, New York City.

'The Study and Teaching of History,' by Miss Lucy M. Salmon, Vassar College.

'The Study and Teaching of Geography,' by Dr. Jacques W. Redway, of New York.

'The Study and Teaching of English,' by Percival Chubb, of the Ethical Culture Schools, New York.

'The Study and Teaching of Mathematics,' by

David Eugene Smith, Ph.D., State Normal School, Brockport, N. Y.

IT is announced that the government has compiled a History of the Territory of Alaska, bringing the explorations made by army officers up to date and including an elaborate description of the physical resources of the Territory. The compilation when published will make a large octavo volume of about 500 printed pages. The material was supplied, by the War Department under the direction of Assistant Secretary Meiklejohn, to the Senate.

BOOKS RECEIVED.

General Physiology. MAX VERWORN. Translated from the second German edition and edited by FREDERIC S. LEE. New York and London, The Macmillan Company. 1899. Pp. xvi + 615. $4.00.

L'audition et ses organes. M. E. GELLÉ. Paris, Alcan. 1899. Pp. 326.

La Céramique ancienne et moderne. E. GUIGNET and EDOUARD GARNIER. Paris, Alcan. 1899. Pp. 311.

The Theory of the Leisure Class: an Economic Study in the Evolution of Institutions. THORSTEIN VEBLEN. New York and London, The Macmillan Company. 1898. Pp. vii + 400. $2.00.

SCIENTIFIC JOURNALS AND ARTICLES.

THE American Mathematical Society is actively pushing the plans for the publication of its Transactions, and it is probable that the first number will appear in January next. A committee, consisting of Messrs. T. S. Fiske, R. S. Woodward, E. H. Moore, Maxime Bôcher and James Pierpont has been appointed to secure the necessary financial guarantees. Subscriptions of one hundred dollars annually for a term of five years have already been pledged by representatives and friends of each of the following institutions: Chicago University, Columbia University, Yale University and Bryn Mawr College. Other pledges are anticipated and the plan is already assured of success.

The Journal of Geology, Vol. 7, No. 1, for January and February, contains the following papers:

Frank Leverett: 'The Lower Rapids of the Mississippi River,' pp. 1–20. The writer discusses the abandonment by the Mississippi River of its pre-glacial channel just above Keokuk, Ia., and the production of the newer and more contracted channel, in which are the rapids. The Kewatin ice sheet and its drift are regarded as the principal cause.

H. B. Kümmel: 'The Newark Rocks of New Jersey and New York,' pp. 23–53. The writer divides the strata under consideration into the Stockton, Lockatong, Brunswick and Trap formations. Their distribution, character, folding and faulting, and the conditions prevailing during their formation, are then discussed.

Henry S. Washington: 'The Petrographical Province of Essex County, Mass.,' II., pp. 53–64. The paper continues one that was begun in the last number. It describes, with analyses, the essexites, diorites, quartz-augite-diorites, porphyritic diorites and gabbros.

J. A. Udden: 'The Sweetland Creek Beds,' pp. 65–79. The beds are chiefly shale, and lie between the Cedar Valley Limestone below and the Coal Measures above, in Muscatine county, Ia. Fossils indicate an Upper Devonian Age.

G. H. Squier: 'Studies in the Driftless Region of Wisconsin,' pp. 79–83. One glaciated boulder has been found in a valley within the driftless region.

W. N. Logan: 'A Discussion and Correlation of certain Subdivisions of the Colorado Formation,' pp. 83–92. The paper discusses and correlates the subdivisions of this formation in the Kansas, Colorado, Black Hills and Iowa-Nebraska areas.

Editorials and reviews complete the number.

THE leading article in the *American Naturalist* for February, is by Dr. W. H. Dall, and discusses 'The Proposed University of the United States and its possible Relations to Scientific Bureaus of the Government.' Dr. Arthur Hollick continues the consideration of 'The Relation between Forestry and Geology in New Jersey,' this paper giving 'The Historical Development of the Flora,' concluding that the gradual extinction of the gymnosperm type is indicated. Professors J. H. Comstock and J. G. Needham also continue the subject of 'The Wings of Insects,' the chapter being devoted to the specialization of wings by addition as illustrated by the venation of the wings of Ephemerida. Under the title of 'The Peneplain: a Review' Dr. R. A. Daly considers at length Professor Tarr's objections to the exist-

ence of peneplains on this earth of shifting base levels. Professor F. L. Washburn describes and figures the shoulder girdle of 'A Peculiar Toad,' presenting the abnormality of an extra (left) fore limb. The abundant literature on the subject of the Trenton Gravels receives an addition from Dr. Frank Russell, who describes some 'Human Remains from the Trenton Gravels,' concluding that the skulls which are figured are those of modern Indians, probably of the Lenni Lenapé. A goodly proportion of Notes and Reviews fill out the number.

THE *Journal of the Boston Society of Medical Sciences* for January comprises two parts, each containing a number of excellent plates. Those illustrating the articles on the 'Pathological Histology of Acute Lacunar Tonsilitis,' by J. L. Goodale, and the 'Character of the Cellular Exudation in Acute Keratitis of the Rabbit,' by W. T. Councilman, are particularly fine. Our anti-vivisection friends who discredit the exist ence of hydrophobia would do well to read the paper by Langdon Frothingham on 'Rabies in the Vicinity of Boston,' where 20 positive cases are noted between March, 1897, and December, 1898. An interesting series of 'Observations on the Effects Produced by the 6-mm. Rifle and Projectile,' by H. G. Beyer, is well calculated to create respect for the new Navy arm.

THE *Botanical Gazette* for February contains the following leading articles: 'New or Little Known North America Trees,' C. S. Sargent 'The Ecological Relations of the Vegetation on the Sand Dunes of Lake Michigan,' Henry C. Cowles; 'The Society for Plant Morphology and Physiology—Columbia Meeting,' W. F. Ganong. The briefer articles include: 'Notes on the Maximum Thermal Death-point of Sporotrichum Globuliferum,' B. M. Duggar; 'Descriptions of Two Willows from Central America,' W. W. Rowlee; 'A Peculiar Case of Spore Distribution,' F. L. Stevens; 'A New Silphium,' Wm. M. Canby.

SOCIETIES AND ACADEMIES.

SECTION OF PSYCHOLOGY AND ANTHROPOLOGY OF THE NEW YORK ACADEMY OF SCIENCES.

AT the regular monthly meeting of the section, on February 24th, papers were presented by R. S. Woodworth on the 'Accuracy of Movement, by F. C. Spencer on the 'Origin and Persistent Influence of Sacred Number Concepts,' and by F. Boas on 'Anthropometric Charts.'

Dr. Boas presented the results of recent investigations, which show that the anthropometric charts now used in the gymnasium by anthropologists are valueless as a means for estimating the development of individuals.

CHAS. B. BLISS,
Secretary.

ONONDAGA ACADEMY OF SCIENCE.

AT the January meeting annual reports of officers and sections were received and the following officers were elected: President, John Van Duyn, M.D.; Vice-President, J. A. Dakin; Secretary, P. F. Schneider; Corresponding Secretary, H. W. Britcher; Treasurer, Miss L. W. Roberts; Librarian, Miss V. L. Jones.

The report of the Geological Section showed considerable progress in the investigation of interesting local problems, and cited the discovery of a vein of quartz crystals in the Corniferous rock at the Onondaga Indian Reservation.

The report of the Botanical Section included new localities for several of the rarer plants of the county. One plant, *Glaucium glaucium*, was reported as new to the county, and two, *Crepis virens* and *Sanguisorba canadensis*, were reported as new to the State. *Selaginella selaginoides* was also found and is probably new to the State.

The report of the Zoological Section contained the result of feeding experiments on the larvæ of *Diedamia inscripta*. During the year upwards of thirty spiders were added to the list of Onondaga county species. Of these, nine species had not hitherto been reported in the State.

H. W. BRITCHER.

DISCUSSION AND CORRESPONDENCE.

WHAT IS THE CAUSE OF THE SO CALLED TOBACCO FERMENTATION?

THUS far it has been generally believed that the rise of temperature and the chemical changes that take place when the cured tobacco leaves are piled up in heaps are due to bacterial action. But careful investigations of the 'fer-

menting' leaves revealed the absence of extended bacterial colonies, the presenc of which were naturally to be expected if *bacteria* were the cause of the phenomena in question. The true cause, I have recently established beyond a doubt, is the presence of two kinds of *oxidizing enzymes* in the tobacco leaves. As soon as the Bulletin describing these investigations is published a full review will be given in this JOURNAL.

OSCAR LOEW.

DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY, U. S. DEPT. OF AGRICULTURE.

THE ANÆSTHETIC EFFECTS OF A SINUSOIDAL CURRENT OF HIGH FREQUENCY.

TO THE EDITOR OF SCIENCE: In your issue of June 3, 1898, I had the honor of communicating an observation on the anæsthetic effects of a sinusoidal current of high frequency. I take the liberty of sending you the following further observations.

a. The anæsthetic effect may be produced by sending the current longitudinally along the the nerve. Thus, a current sent along one of the nerves of the arm can be used to produce anæsthesia in parts of the arm supplied by it. With a pleasant current of about 28,000 alternations per second passing between the elbow and the hand, a needle can be painlessly run into the forearm.

b. At the suggestion of Professor B. Moore, of the Yale Medical School, I applied the current to the tongue, with a view to testing the theory that the sensation of taste may be due to vibratory stimuli. If the theory were true the fluctuations in the sinusoidal current might be expected to produce sensations of taste of various kinds. The experiment showed that fluctuations up to about 29,000 complete periods per second produce no sensations of taste whatever; the only sensation is that of tickling and puckering.

c. It should perhaps have been stated in my original communication that the main purpose of the investigations with the sinusoidal current was to determine the various sensations at different frequencies. They have been determined for two subjects as follows: (1) Threshold of sensation of touch at a frequency of about 480 complete alternations per second; (2) threshold of disagreeableness at about 840; (3) threshold of pain at about 960; (4) disappearance of pain at about 1,440, followed by a peculiar, agreeable sensation; (5) disappearance of agreeableness at a point not yet determined, followed by a faint sensation; (6) disappearance of sensation at a point not yet determined. For constant conditions these figures are quite constant, the probable error ranging from $\frac{1}{10}$ of 1 % to 4 %.

d. Applying the electrodes to the nerves of the arm in a way to move the muscles of the forearm and hand I find a similar neuromuscular effect. As the current rises in frequency from zero the muscles contract steadily up to a certain point, after which they gradually relax. The process is the same when we start with a high frequency and descend to zero. The phenomenon can hardly be due to a diminished intensity of the high-frequency current.

e. It may be added that the instrument used is a Kennelly alternator run at a very high speed. Similar high-frequency machines have been used by Nikola Tesla, who has not recorded any of the above phenomena; possibly his machines do not produce sinusoidal currents.

f. Using another machine which simply interrupted a galvanic current up to 100,000 times per second I find that above a certain point (not yet measured) the interruptions cease to have any effect other than merely reducing the strength of the current when it is sent through the tissues.

E. W. SCRIPTURE.

YALE UNIVERSITY, NEW HAVEN, CONN.,
February 28, 1899.

NOTES ON PHYSICS.

THE METRIC SYSTEM.

THE Hartford Steam Boiler, Inspection and Insurance Company of Hartford, Conn., has issued a very neat and convenient volume, of 'pocket size,' containing tables for the Conversion of English weights and measures into their metric equivalents, and *vice versa*. It opens with a very interesting discussion of the metric system, which lacks, however, any recognition of the International Bureau of Weights and

Measures and the great work it has accomplished during the past twenty-five years. Nothing is said about the International Prototype units of length and mass, which are the real standards of the world to-day, and it is implied that the meter and kilogramme are, except for practical purposes, what they were defined to be a hundred years ago. The ratios of the metric to our customary units used, in the book, are not those legally adopted by the U. S. Office of Weights and Measures, but the differences are so small that the conversion tables are not sensibly in error. There is a growing use of the metric system in this country, the result of an increasing trade with foreign countries, and this book will satisfy every demand of those who are called upon to convert from one system to the other. The tables are so numerous that it is difficult to imagine a call for anything which the book does not contain, and a convenient index renders them quickly available. Much time is saved by carrying the tables up to one-hundred multiples of each unit, but in a few instances space and labor have been wasted in doing this, because of the impossibility of such conditions ever being realized. For instance, in the table for converting 'grammes in a cubic centimeter to ounces in a cubic inch,' there does not appear to be any necessity for going beyond 23 or 24—as there is no known substance denser than this. Thus more than three-quarters of this table can be of no use, and this is true of several tables of a similar character. On the whole the work is exceedingly well done, and the book ought to be much sought after. T. C. M.

THE ELECTROLYTIC INTERRUPTER FOR THE INDUCTION COIL.

When a high electro-motive force is connected to an electrolytic cell, one electrode of which is very small, the rush of current which takes place is quickly interrupted by the layer of gas which is generated at the small electrode. This layer of gas then collects as a bubble, the electrolyte again comes into contact with the electrode, a rush of current again takes place to be interrupted as before, and so on. These interruptions are very abrupt, and their frequency varies from two or three hundred to a thousand or more per second according to the size of the small electrode and the inductance of the circuit. The small electrode should be the anode.

Dr. A. Wehnelt (*Electrical Engineer*, February 16, 1899) has applied this electrolytic interrupter to the induction coil. He uses dilute sulphuric acid, a sheet of lead as cathode, and the tip of a small platinum wire projecting from a glass tube as anode. The interrupter works with entire satisfaction with electro-motive forces as high as 110 volts; the condenser, needed with the ordinary interrupter, is useless; and the effectiveness, especially of small coils, is greatly increased both in length of spark and frequency.

Dr. Wehnelt's experiments have been repeated in the Physical Laboratory at Bethlehem Pa., his results have been confirmed, and it has been found that the primary of an induction coil should be wound with more turns of wire than usual to give the best results with this electrolytic interrupter. The interrupter gives good effects when used to supply intermittent current to the primary of a small transformer. Thus a small step-down transformer taking 375 watts from the mains gave out about 30 watts from its secondary.

When the electrolytic interrupter is used to supply intermittent current from a 110 volt source to the primary of a transformer, the e. m. f. which establishes the current after each break is, of course, 110 volts, while the e. m. f. which stops the current is the e. m. f. between the break points and may be very greatly in excess of 110 volts.

The effective primary e. m. f. is, therefore, on the whole, greatly in excess of 110 volts, so that a 1:1 transformer may give several hundreds of volts at its secondary terminals when supplied with intermittent current from a 110 volt source.

This is shown by the fact that a 220 volt lamp, for example, may be lighted from the secondary, and, of course, it may be lighted equally well or even better if connected across the primary terminals. W. S. F.

THE RESISTANCE OF CARBON AND COPPER BRUSHES.

Professor E. Arnold gives, in the *Electrical Zeitschrift* for January 5th, a study of the 'Con-

tact Resistance of Carbon and Copper Brushes and the Temperature Rise of the Commutator.' He finds that the contact resistance decreases with increase of current density, especially with higher velocities of commutator surface; thus, with a velocity of 368 meters (1205 ft.) per minute, the resistance per sq. cm. is for .7 amp. per sq. cm. .6 ohm., while for 10 amp. it becomes only .1 ohm., beyond which point it is nearly constant. He finds also that for a given current density the resistance increases with speed to a maximum, and then decreases for higher speeds; this he accounts for by supposing an unfavorable relation between the weight of the brush and the periodicity of the vibrations from passing over the segments; this theory is upheld by the fact that the same maximum appears at a lower speed for the heavier copper brush. A highly polished metal surface gives a higher resistance, which oiling increases still further. He mentions eddy currents as producing losses in the segments, and gives formulæ for the friction losses and the rise of the temperature.

F. C. C.

ENZYMES AS REMEDIES IN INFECTIOUS DISEASES.

DURING the past year Drs. R. Emmerich and Oscar Loew have been engaged upon an interesting problem in connection with enzymes as remedies in infectious diseases. The work was carried on in Munich, and as yet the results have not been published in full. We are indebted to Dr. Loew for the following facts in regard to the investigations: It has been surmised by Nencki and by Pfeiffer that the substances leading to recovery from infectious diseases, and producing immunity from them, belong to the enzymes. The latter author believed that these enzymes are prepared by the animal organs and not by bacteria themselves. Dr. de Schweinitz has observed an enzyme in cultures of the hog cholera germ which had a potent action in rendering guinea pigs insusceptible to this disease. However, this enzyme exhibited poisonous action in but little higher doses than necessary for immunizing.

Recently Emmerich and Loew have proved that certain kinds of bacteria, for example, *Bacillus pyocyaneus*, produce enzymes which not only dissolve these bacilli themselves, but also other microbes, such as the germs of cholera, typhoid fever, anthrax, diphtheria, black plague, stapthlococci and probably also gonococci. The germs of tuberculosis and many others are not affected by this enzyme within 24 hours. *Micrococcus prodigiosus* can also produce a bacteriolytic enzyme, which does not appear to act so favorably as that of the Pyocyaneus. The *Micrococcus erysipelatos* produces one, but this is associated, as in many other cases, with very poisonous qualities.* Emmerich and Loew have demonstrated that in a rabbit first infected with anthrax and then treated with subcutaneous injections of the concentrated enzyme of the *Bacillus pyocyaneus* the anthrax bacilli in the spleen are found completely broken up and partly dissolved, exactly as it can be observed in *vitro* when a dose of millions of anthrax and the other named bacilli are transferred into a few cubic centimeters of the concentrated and purified pyocyaneus enzyme. The latter enzyme can, by combination with an animal protein, be transformed into an immunizing substance. The authors have succeeded in obtaining both these agencies in a durable solid form. Thus the time seems near at hand when the treatment with serum will be replaced by a cheaper and simpler method, at least in certain cases.

B. T. GALLOWAY.

SCIENTIFIC NOTES AND NEWS.

THE refusal of Congress to establish a permanent census bureau for the proper conduct of the work has had its natural sequence in the appointment of a politician as Director of the Twelfth Census. The best that can be said of ex-Governor Merriam is that he had a creditable record as Governor of Minnesota. The New York *Evening Post* speaks of the appointment as follows: "Mr. Merriam is appointed Director of the Census simply because there was no other good office vacant at home or abroad. He has never had any experience as

*The bacillus of the black plague, that of tuberculosis, and other kinds, seem incapable of producing bacteriolytic enzymes, at least not to any noticeable degree, and the serum of black plague has, therefore, been applied without success in the cases at Vienna.

a statistician, and possesses none of those expert qualifications which the place imperatively demands. He is a spoilsman, and can be trusted to run the bureau on a spoils basis, from top to bottom. No appointment could be made which would so certainly secure the failure of the next census as a trustworthy and creditable work."

Mr. F. H. Wines, who has been appointed Assistant Director of the Census, is an expert statistician.

The nomination of Mr. Barrows as Librarian of Congress has failed of confirmation by the Senate. It is to be hoped that the action of the Senate was due to the fact that Mr. Barrows is not a librarian by profession, and not to the fact that he is a good executive officer, who would probably have administered the National Library without regard to party considerations.

The civilian members of the United States Philippine Commission, President Schurman, of Cornell University; Col. Charles Denby, and Professor Dean C. Worcester, of the University of Michigan, have arrived at Manila.

D. Anton Fritsch, Director of the Natural History Museum of Prag, who has just begun publishing the fourth volume of his *Fauna der Gaskohle* of the Permian of Bohemia, sails for New York in the *Kaiser Wilhelm* on March 28th, to visit the museums of this country.

Professor T. E. Thorpe, F.R.S., has been nominated for the presidency of the Chemical Society, London, and Mr. William Whitaker, F.R.S., has been elected President of the Geological Society, London.

We regret to learn that Dr. J. J. Valentini, the student of Mexicana, is seriously ill with pneumonia at St. Luke's Hospital, New York City.

Dr. H. Foster Bain, Assistant State Geologist of Iowa, is delivering a course of lectures on economic geology to the graduate students in geology at the University of Chicago. Dr. W. S. Beyer, professor of geology and mining in the Iowa State College of Agriculture and Mechanic Arts, has charge of the office of the Iowa Geological Survey at Des Moines during Dr. Bain's absence.

Mr. M. A. Carleton, who has been engaged for several years upon an investigation of the rusts affecting cereals, has just returned from Russia, where he has been collecting cereals for use in this country in connection with the investigations now being carried on by the Section of Seed and Plant Distribution. Mr. Carleton has collected much valuable material and information which will further the work of the Division of Vegetable Physiology and Pathology on cereal diseases and the breeding of new and valuable varieties.

Arrangements have been made by the Rothschilds to send Mr. G. W. Dunn on an expedition to the Philippine Islands for the collection of objects of natural history. Mr. Dunn has made many collecting expeditions to South America and Mexico. He is at present 85 years of age.

Signor Marconi described and demonstrated his method of wireless telegraphy at a meeting of the British Society of Electrical Engineers on March 2d.

The Academy of Sciences of Vienna has made a new departure in entertaining at a banquet Dr. Gerhardt Hauptmann, the eminent dramatic writer. Dr. Ed. Suess, the President, presided and made an address in honor of Dr. Hauptmann.

On the retirement of Mr. W. H. Preece, C.B, the British Postmaster-General has appointed Mr. J. Hookey, previously assistant engineer-in-chief, to be engineer-in-chief of the post office, and he has also appointed Mr. J. Gavey to be assistant engineer-in-chief and electrician.

M. Bouquet de la Grye has been appointed President of the Council of the French Bureau of Meteorology. M. Darboux has been appointed Vice-President and M. Anthoine, Secretary.

Dr. Allan McLane Hamilton, professor of mental diseases in Cornell Medical College, has been elected a member of the Royal Society of Edinburgh.

A Civil Service examination will be held on April 11–12, 1899, for the position of Assistant in Irrigation, Office of Experiment Stations, Department of Agriculture, at a salary of $1,500 per annum. The examination will consist of

the subjects mentioned below, which will be rated as follows:

Subjects.	*Weights.*
1. Drafting,	30
2. Theory and practice of irrigation,	20
3. Irrigation engineering,	20
4. Essays on irrigation subject,	20
5. Training and experience,	10
Total,	100

WE learn from *Nature* that at the annual meeting of the Russian Geographical Society, on February 2d, the following medals were awarded: The Constantine medal to Dr. Gustav Radde, the director of the Tiflis Museum, for his forty-five years' work in the study of Russia; the Count Lütke medal to I. I. Pomerantseff, for his researches into the forms of the earth's geoid in the province of Fergana; the Semonoff medal to M. Kleiber, for his investigations into the periods of high water in the Volga; the great gold medal of the Section of Ethnography to N. L. Gondatti, for his three years' work of exploration of the Land of the Chuckchis; the Przewalski medal to L. A. Jaczewski, for his physico-geographical researches in Siberia; and three small gold medals to M. Tachaloff, for his instruction of travellers in astronomical observations; A. A. Rostkovsky, for a map of population in the Bitol vilayet of Turkey; and N. A. Zarudnyi, for researches in Persia; a number of silver medals were awarded for minor works.

IT is proposed to establish, with the sum of $5,000, at the University of Glasgow, a prize in pathology in memory of the late Professor Joseph Coats.

STEPS are being taken to found a memorial in honor of the late Robert Hebert Quick, who accomplished much for the advancement of education in Great Britain. It is hoped that £500 may be collected and used to endow a Quick Memorial Library at the Teachers' Guild, London, where Mr. Quick's educational library is at present deposited. Subscriptions may be sent Mr. John Russell, Cripplegate, Woking Surrey.

ARRANGEMENTS are being made to collect a fund in memory of the late Professor Kanthack. Owing to his early death, Mrs. Kanthack is not sufficiently provided for, and it is proposed that the income of the fund be given to her and at her death be used for a permanent memorial to commemorate his important contributions to pathology. Subscriptions may be sent to Dr. J. H. Drysdale, 25 Welbeck-street, London, West.

MAJOR GENERAL JOSEPH J. REYNOLDS, U. S. A., formerly professor of mechanics and engineering at Washington University, St. Louis, and during and since the Civil War a distinguished officer of the army, died on February 26th, at the age of 77 years.

THE death is announced of Alexandre Laboulbene, professor of the history of medicine in the University of Paris, at the age of 73 years. Dr. Laboulbene had not only published valuable works on the history of medicine, but was also well known as a pathologist and entomologist, having published a 'Traité d'Anatomie Pathologique' and a 'Faune Entomologique Française.'

WE regret also to record the death of Dr. William Rutherford, professor of physiology in the University of Edinburgh, which occurred on February 21st, from a relapse following influenza. We learn from the London *Times* that Professor Rutherford was born at Ancrum Craig, Roxburgshire, in 1839, and was educated first at Jedburgh Grammar School, and afterwards at Edinburgh University, where he graduated with honors in 1863, obtaining a gold medal for his thesis. He held office as house physician and house surgeon in the Edinburgh Royal Infirmary under Dr. Rutherford Haldane and Professor Spence, and then taught anatomy for a year in the Surgeons'-hall under Dr. Struthers. He afterwards went to the Continent and studied at the great medical schools of Berlin, Vienna and Paris. In 1865 he was appointed University assistant to the late Professor John Hughes Bennett. In 1869, when only 30 years of age, he was appointed professor of physiology in King's College, London, a post which he filled for five years, during three of which he was also Fullerian professor of physiology in the Royal Institution, London. His reputation as a teacher and lecturer spread rapidly, and in 1874, on the resignation of Professor Hughes Bennett, he was appointed to the chair of physiology in Edinburgh University.

Here he labored till the close of his life, and did much to develop the practical teaching of physiology, both in lectures and by the institution of practical classes. His chief work was 'The Action of Drugs on the Secretion of Bile,' and he was also the author of 'Outlines of Practical Histology,' and a 'Text-book on Physiology,' besides many papers on various scientific subjects. His recent efforts were chiefly directed to the study of hearing, sight and other special senses. He was also the inventor of the freezing microtome, which has proved of great value in microscopical research and demonstration. In 1876 Professor Rutherford was elected a Fellow of the Royal Society of London.

THE French Mathematical Society is making active arrangements for the International Congress of Mathematicians, to be held at Paris, from the 6th to the 12th of August, 1900. Replies have already been received from 900 intending members. A meeting was recently held at Göttingen, at which representatives of the Academies of Vienna, Munich and Leipzig were present for the purpose of planning a program for the Congress.

A COMMITTEE, of which Professor Newcomb is the chairman, is collecting information in regard to the best methods for observing the total eclipse of the sun on May 28, 1900. The track of the shadow runs from New Orleans to Norfolk and across to Spain and Algeria. Arrangements are also being made by the British Astronomical Society. A paper was read by Mr. A. C. D. Krommelin before the Society on February 22d. As a result of a close study of the weather statistics the conclusions he drew were: (1) That Algiers was certainly worth occupying on account of its low cloud ratio, it accessibility and its excellent harbor; (2) that the Portuguese stations had a higher cloud ratio, but a longer totality (1 min. 36 sec., as compared with 1 min. 6 sec. at Algiers); (3) the region south of Madrid had a low cloud ratio, and several railway lines cut the shadow track, so that there would be no difficulty in transporting instruments; (4) the Alicante region seemed less clear than central Spain, but more so than Portugal. The Association's special steamer could land detachments at various points on the Portuguese and Spanish coasts, and then proceed to Algiers with the remainder of the party. It could remain at Algiers as a floating hotel to the party, and after the eclipse return by the same route, picking up the various detachments.

American Gardening, New York City, offers prizes amounting to $150 for papers on hybridization treated from the point of view of its relations to science and horticulture. The papers must be between 1,000 and 5,000 words in length and must be sent in before April 15th.

THE Paris Academy of Sciences has received a legacy of 35,000 fr. from M. Paul Frédéric Hély d'Oissel.

THE late Dr. E. F. A. Obach has bequeathed his scientific library to the Siemens' Engineering Society, Woolwich, with the exception of his special library on india rubber, which, with specimens, etc., is left to the Botanical Museum, Berlin.

THE Zoological Society of London has subscribed £200 towards the fund being collected for a British Antarctic expedition.

THE Goldsmith's Company, London, has made a further grant, this time of £500, for the the continuation of experiments on the antitoxin treatment of diphtheria undertaken under the direction of the Royal Colleges of Physicians and Surgeons.

A HUNDRED-YEAR Club has been established in New York City, and will be glad to receive members whose only duties are to pay the annual fees and to try to pledge themselves to endeavor to live and persuade others to live more than a hundred years. A beginning has been made by a dinner at the Waldorf-Astoria.

IN connection with the work on pear blight conducted by Mr. M. B. Waite, of the Division of Vegetable Physiology and Pathology, United States Department of Agriculture, an interesting feature has been developed in the way of growing the bacillus of blight on dormant pear shoots. The fact that the organism could be grown in this way was discovered by Mr. Waite about two years ago, and it furnishes means of throwing light on a number of points connected

with the disease. For illustrative purposes in class rooms or elsewhere it forms one of the most striking examples of the effects produced by a bacterial plant disease. Shoots the size of a lead pencil or a little larger are cut from pear trees, and after being washed in a clean water their upper ends are cut in a slanting way with a sharp sterilized knife. The shoots are then placed in a glass containing water, with the slanting ends free. The glass and its contents are now set in a plate or dish containing water, and a bell jar or large beaker placed over them in such a way that the rim is immersed in the water in the plate. This insures a saturated atmosphere and other conditions unfavorable to the shoots, but favorable to the germs themselves. Infections with pure cultures of the blight bacillus on the slanting cut surfaces of the shoots begin to show as beautiful, pearly-white, bead-like colonies in from 36 to 48 hours, and as the disease progresses, which it does more or less rapidly under varying conditions of heat, the changes in the host and parasite may be easily watched.

THE new *Turbinia*, of 220 feet in length and 330 tons displacement, is, as we learn from the London *Times*, in an advanced state of construction at Ellswick, and hopes are being entertained of her being tried in two months from the present time. The modifications found to be desirable after the exhaustive trials of her predecessor are considerable. The new vessel has eight propellers on four shafts, instead of the original *Turbinia's* three shafts and nine propellers. Her 'going-astern' arrangements are far in advace of those of the pioneer boat, whose extreme speed caused great excitment in the Solent at the time of the Naval Review of 1897.

UNIVERSITY AND EDUCATIONAL NEWS.

PRESIDENT TAYLOR, of Vassar College, has declined the call to the presidency of Brown University.

MR. A. E. H. LOVE. F.R.S., Fellow of St. John's College, Cambridge, and University lecturer in mathematics, has been appointed Sedleian professor of natural philosophy in succession to the late Professor Bartholomew Price.

MR. A. W. HILL has been appointed demonstrator in botany in Cambridge University.

ROLLINS A. EMERSON, of Washington, D. C. who was elected to the chair of horticulture in the University of Nebraska in June, 1898, assumed the duties of the position March 1st. After resigning his position in the Division of Experiment Stations in the Department of Agriculture, he spent some time in study in Cornell University before taking up his new duties.

DR. H. E. ANNETT has been appointed demonstrator of tropical pathology in the newly-founded school of tropical diseases in Liverpool. Both Edinburgh and Aberdeen have taken steps to establish lectureships on the diseases of tropical climates.

THE chair of natural history at Aberdeen, vacant by the death of Professor Nicholson, will, it is expected, be divided, and professorships of geology and zoology will be established.

THE late Mrs. Martha S. Pomeroy has bequeathed to Wellesley College $60,000 for the erection of a dormitory, and also the residue of her estate.

WE are also glad to record the following gifts and bequests: Miss Maria Hopper has given $10,000 to Bryn Mawr College for the foundation of a scholarship. Syracuse University has received $5,000 from the heirs of H. H. Crary, of Binghamton, in accordance with the wishes he had expressed. The University of North Carolina has been given $15,000 by Mr. Julian S. Carr. Swarthmore College has received $5,000 by the will of the late Daniel Underhill.

THE late Professor Rutherford has bequeathed to Edinburgh University his valuable medical library and his collection of physiological and microscopical specimens.

ON the fifteenth of February the University of Nebraska celebrated its thirtieth anniversary. It has been the custom for many years to observe 'Charter Day' as a holiday, and to have parades, military exercises, addresses, etc., and for several years degrees have been conferred upon such students as completed their work at this time. On the present occasion seven students received the bachelor's degree and two

the master's degree. The University address was given by Dr. A. F. Nightingale, Superintendent of High Schools, Chicago. During the evening exercises Governor Poynter made the welcome announcement that he had that morning signed the 'University Revenue Bill' and that it was now the law of the State. This bill is one in which all the friends of the University were much interested. It provides first for the classification and handling of the funds of the University, as follows: The permanent endowment fund, the temporary University fund, the University cash fund, the United States Morrill fund and the agricultural experiment station fund, and requires that the State Treasurer shall be the custodian of all University funds. The second and by far the most important provision is that by which the University tax is increased from three-eighths of a mill to one mill on each dollar of valuation of the 'grand assessment roll' of the State. This will place a much larger sum in the hands of the Regents of the University and will enable them to plan for larger things in the future. It is one of the most important acts of any Legislature in Nebraska in its bearing upon higher education.

We hope that the following item printed in the San Francisco *Call* is correct: "Three measures for the benefit of Stanford University have been presented in the California Senate. They are in the form of amendments to the political code, allowing corporations formed for educational purposes to accept gifts and bequests. When the bills finally become laws Mrs. Stanford stands ready to turn over her own personal fortune of more than $5,000,000 to the college, and Governor Stanford's brother, who has made a fortune in Australia, will turn over in installments nearly $15,000,000 more. This vast sum, with the present funds at the disposal of the college, will place it on a financial standing far beyond its competitors. Under the present provisions of the codes an educational institution cannot accept a gift or bequest. It was the intent of the law to prevent certain eleemosynary institutions from securing possession of large tracts of land and sums of money, and hold them, with no benefit to anyone, and so when it was desired to endow the University with all the Stanford millions it was found to be impossible to do so under the laws of the State. It was about a year ago that the Australian Stanford first broached the subject of adding his millions to those of his brother. It had always been Governor Stanford's wish that his childless and kinless brother should follow his example regarding the University, and a year ago it was decided to bring the two fortunes together."

The annual report of President Eliot, of Harvard University for 1897, is, as usual, an educational document of great importance. With the appended reports of the deans of the faculties and schools and the directors of the scientific establishments it contains 322 pages, and the report of the Treasurer is given in much detail, occupying 89 pages. Among the subjects considered is President Eliot's favorite plan of reducing the College course to three years, it being pointed out that more than one-third of the students do practically complete the work required in this time. It is noted that men of high scholarship are fully equal to others in physical development, as shown by the gymnasium records. President Eliot finds that during the past twenty-seven years the number of members of the faculty has increased more rapidly than the number of students and that the average ages of the members of the faculty has decreased by less than one year. The instructors of the first three classes are considerably older than formerly, while the instructors of the senior class are younger. The average age of the Harvard instructor is about forty years. During the year the requirements for admission to Harvard College and the Lawrence Scientific School were revised in a manner favorable to the sciences. The text-book study of physics and astronomy is omitted and four new subjects are offered, namely, astronomy, physiography, meteorology and anatomy, with physiology and hygiene. No reason is given for not allowing zoology or botany to be elected, yet these are perhaps the sciences which can be best taught in the ordinary preparatory schools. The terms of admission to the Lawrence Scientific School will, we are glad to learn, gradually be raised to substantial equality with those of of the College.

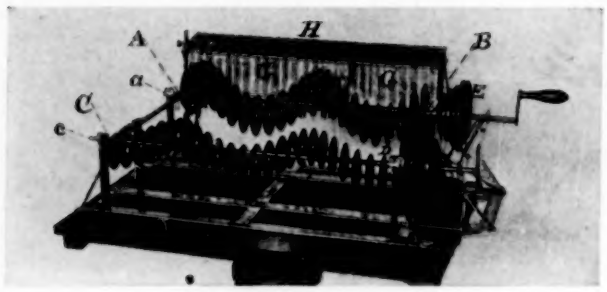

FIG. 1. Belt plate, etc.

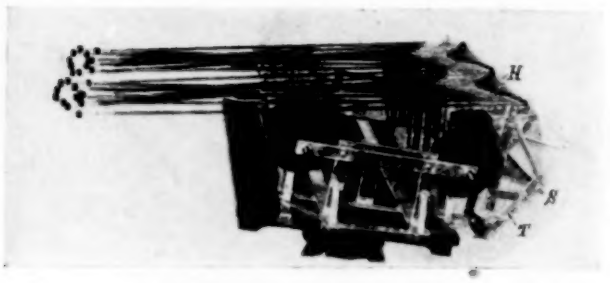

FIG. 4. Adjustment for transverse space waves.

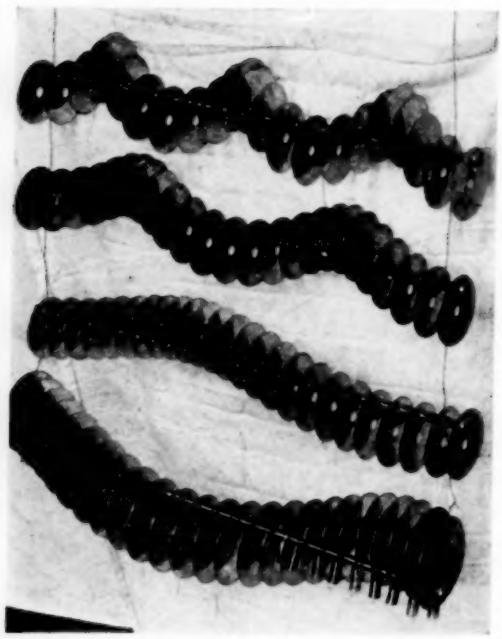

FIG. 2. Cam axles with one, two and three wave-lengths.

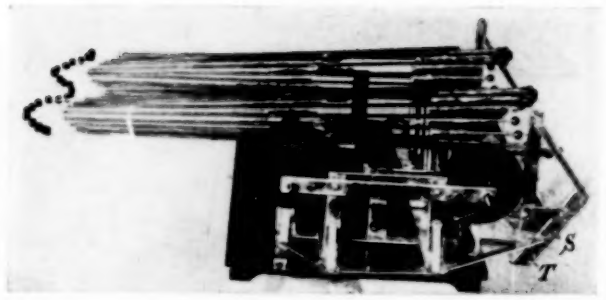

FIG. 5. Adjustment for compounding circular and plane polarized waves.

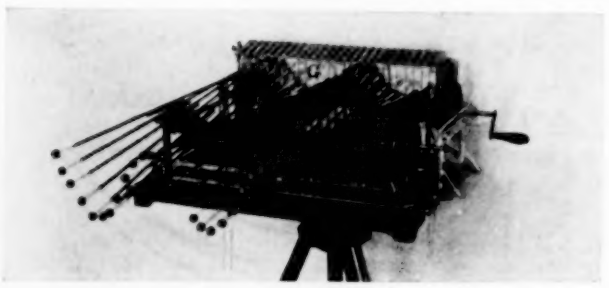

FIG. 3. Adjustment for plane polarized waves.

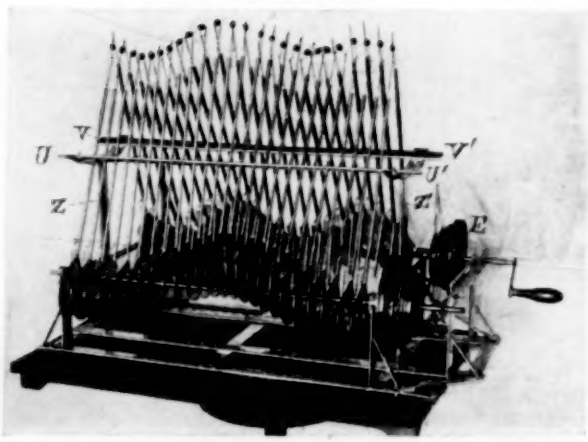

FIG. 6. Adjustment for rotary polarization.